BIOFERTILIZER STUDIES IN SOIL AND PLANT RELATIONSHIP

A

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CERTIFICATE

I hereby certify that the thesis entitled "BIOFERTILIZER STUDIES IN SOIL AND PLANT RELATIONSHIP" Submitted to the UNIVERSITY OF ALLAHABAD for the award of the degree of DOCTOR OF PHILOSOPHY IN AGRIL. CHEMISTRY & SOIL SCIENCE, embodies the results of a bonafide research work carried out by Shri Arun Kumar Singh under my guidance and supervision.

To the best of my knowledge, experimental observations and data presented in the thesis are genuine and original.

MMVerma
(M.M. VERMA) 21.12.2K

Supervisor

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A. K. Singh
(Arun Kumar Singh)

CONTENTS

LIST OF ABBREVIATIONS USED

A.A.S.	–	Atomic Absorption Spectrophotometer
C.D.	–	Critical Difference
Conc.	–	Concentrate
CEC	–	Cation Exchange Capacity
CMS	–	Centimeters
C	–	Celsius
D.A.S.	–	Days After Sowing
D.M.Y.	–	Dry Matter Yield
D.W.	–	Dry Weight
DTPA	–	Diethylene Triaminepenta Acetic Acid
d Sm^{-1}	–	decisiemen per meter
EDTA	–	Ethylene Diaminetetra Acetic Acid
EC	–	Electrical Conductivity
F.Y.M.	–	Farm Yard Manures
m	–	Metre
M.R.P.	–	Mussorrie Rock Phosphate
N.P.K.	–	Nitrogen Phosphorus Potash
N. S.	–	Non Significant
OC	–	Organic Carbon
pH	–	Negative log of the hydrogen ion activity
PPm	–	part per million

INTRODUCTION

INTRODUCTION

At the global level, considerable progress has been made in the field of agriculture production among developing countries, India has made unparalleled progress during its post-independence period by increasing food grains production from 51 mt to 171 mt and achieving more than double the output of cotton and three times that of sugar. However, with the adoption of intensive agriculture, problems like water logging, soil salinity, nutrient deficiency, soil sickness, etc. have developed, which need attention for sustaining the productivity rate.

Swaminathan (1997) has emphasized that agriculture production has increased due to high yielding varieties and enhanced consumption of chemical fertilizer and water in India. Due to high cost of energy utilised in fertilizer industry resulting increased price rise may be a limiting factor for increasing agriculture production in future, it is therefore, essential for us to evolve and adopt a strategy for nutrient supply by using a judicious combination of chemical fertilizer, organic manures and biofertilizers.

Biofertilizers are culture of microbes which benefit the plant by providing nitrogen or phosphorus by rapid mineralization of organic materials. They may be classified as nitrogenous, phosphatic or cellulolytic depending on their physiological activities. These carrier based inoculants are prepared from selected efficient strains after a series of testing invitro and invivo conditions.

Natrajan *et al*, (1989) emphasized that there is a possibility of meeting a large part of the total nitrogen demand through proper husbandry of micro-organisms in crop production systems. The most widely used biofertilizer, Rhizobium in association with legume can fix more than 100 kg N/ha in one

season and in certain situations leave substantial quantity of nitrogen for the following crop. The use of blue green algae as a biofertilizer for rice has promising potential azolla in association with blue green algae fixes 100-150 KgN/ha annually from about 40-60 tons of bio mass. Inoculation of rice with Azosprillium at 75 percent of the recommended N gave yield at par with the full dose of N application.

Agro-chemicals are being applied to soils and plants in the intensive agriculture programme. These chemicals ultimately reach the soil where they temporarily or permanently change the microbial equilibrium and many of them are known to affect non-target organisms including beneficial plant microbial associations such as Rhizobium legume symbiosis and mycorrhizal associations. The effect of these chemicals in the biosphere has generated massive world wide research programmes focussed directly or otherwise on environmental quality. Mishra (1985)

Rhizobium was the first microbial fertilizer to be used on a large scale. Apparently there are specific Rhizobium to every legume and inoculation with efficient strain of rhizobia is essential for the nitrogen gains and better crop yields. According to Gaur (1987) inoculation of pulse crop with appropriate culture can give increased yield upto 15-30 percent. The response of rhizobia inoculation at the farmers field with respect to pulse crops viz., Arhar, Moong, Cowpea, Urad and Moth have been demonstrated. The result showed on an average an increase of about 10-15 percent over uninoculated control.

The relationship between the formation of nodules and nitrogen assimilation was first demonstrated in 1888 by Hellriegel and Wilfarth but more than a half century elapsed before studies using N^{15} nitrogen provided unequivocal proof that nodules are the seat of the fixation reaction. The localization of the N-mobilizing enzymes in the modified root tissue

suggests that nodulation and the associated biochemical processes are of prime importance to the well-being of leguminous crops.

Innoculation of plants with Azotobacter chroococcum can effect their growth and sometimes increase crop yield but the reasons are not known. Azotobacter may directly affect plant growth either by the nitrogen it fixes or by producing growth-promoting substances or indirectly by changing the microflora in the rhizosphere and affecting the balance between harmful and beneficial organism.

Soviet workers claimed control of soil-borne plant diseases by Azotobacter inoculation. Because the plant absorbs its nutrients from the soil near its root and is subject to attack by root parasites the microbial activities in the rhizosphere are clearly important in influencing plant growth.

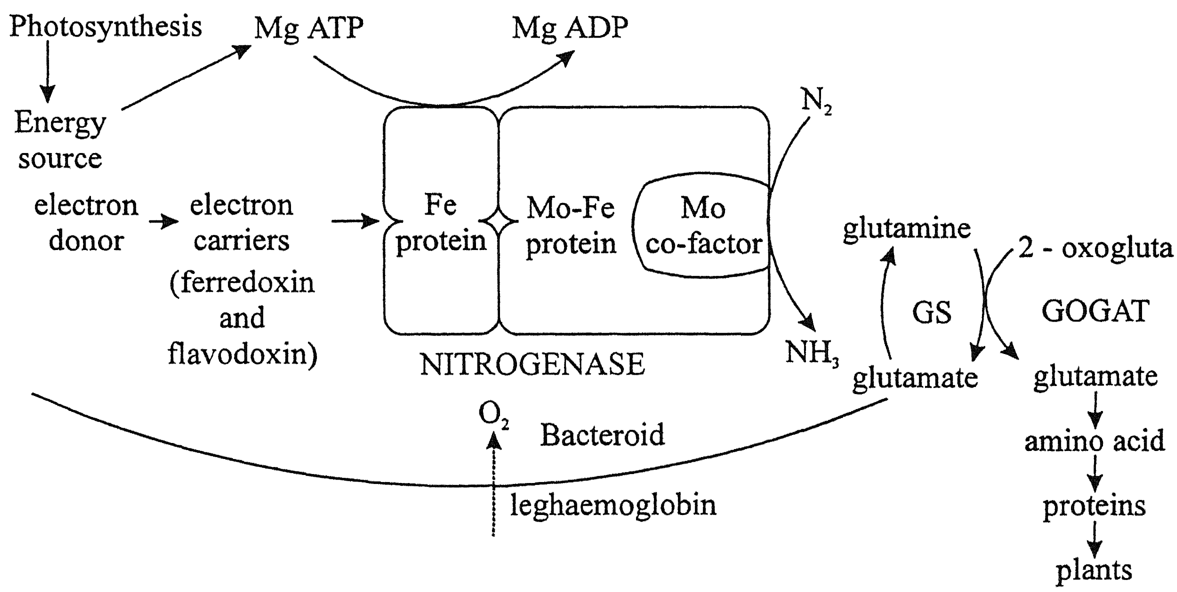
Phosphorus dissolving micro-organisms have capability to render insoluble forms of phosphate more available to plants. Some new promising phosphorus solubilising bacteria and fungi such as Pseudomonas striata, Bacillus polymixa, Aspergillus awamori, Penicillium digitatum have been isolated at IARI and tested in fields.

Recently, Subba Rao (1993) emphasised that possibility of greater utilization of indegenously available rock phosphate resources by the action of phosphate-solubilizing microorganisms. In this connection, field experiments have been carried out in India using culture suspensions of B-polymixa, B-circulans, P-striata, and Aspergillus awamori with and without super phosphate or rock phosphate on the yield of wheat and rice (Gaur *et al*, 1980). The result demonstrated that significiant increase in grain yield was possible when wheat was inoculated with P. striata in the presence of rock phosphate at 100 kg P_2O_5 ha-1. Similarly, grain yield significantly increased when rice was inoculated with B-polymixer in the presence of rock phosphate.

Shahi (1999) has emphasised that restoration of soil fertility is possible by replacement of plant nutrients through the integrated supply system (INSS). The integrated nutrient supply system ensures the maintenance of soil fertility and crop productivity by utilising all possible sources of organic, inorganic and biofertilizers in a judicious and synchronous manner. Researches reveal that a decline in the crop yield can be arrested to a considerable extent with the balanced application of nutrients by an integrated use of chemical fertilizers. F.Y.M./compost, in situ grain manuring biofertilizer, sulphitation pressmud and fresh mulching.

According to Subba Rao (1977) the biochemistry of symbiotic nitrogen fixation is still to be worked out. Nevertheless, an overall picture can be built up from results available from experiments with nodule homogenates and cell-free extracts of bacteroids. The amounts of photosynthate available to the nodule may be a most significant factor limiting nitrogen fixation and therefore, the major limiting factor controlling N_2 fixation under field conditions may be found in the plant.

An overall scheme for biological N-fixation in a root nodule is illustrated in following figure as suggested by Subba Rao (1993).



An overall scheme for biological nitrogen fixation in a root nodule

The functioning of the nodule may be influenced by charges interoperatune, light intensity, photo periods, the presence of combined nitrogen in soil, pH of soil, miniral nutrition (especially cobalt and molybdenum since the later happens to be an integral part of the enzyme nitrogenase), growth subtances, and the presence of salt and antagonistic micro organisms in soil. (Subba Rao 1977)

The relationship between the formation of nodules and nitrogen assimilation was first demonstrated in 1888 by Hellriegel and Wilfarth but more than a half century elapsed before studies. Using N^{15} nitrogen provided unequivocal proof that nodules are the seat of the fixation reaction. The localization of the N-mobilizing enzymes in the modified root tissue suggests that nodulation and the associated biochemical processes are of prime importance to the well-being of leguminous crops. (Alexander 1977)

Soviet workers claimed control of soil borne plant diseases by Azotobacter inoculation. Because the plant absorbs its nutrients from the soil near its roots and is subject to attack by root parasites the microb ial activities in the rhizosphere are clearly important in influencing plant growth.

Tilak and Singh (1996) revealed the contribution of biofertilizers in the integrated nutrient management in sustainable agriculture and summarised the nitrogen fixing potentiality of commonly cultivated leguminous crops and the residual nitrogen availability for subsequent cereal crops in the following table :

Potential N Contribution of Some Legumes

	Fertilizer N equivalents (KgN/ha)	
Crop	**Nitrogen fixing potential**	**Residual effect on succeeding cereal crop**
Alfalfa	100-300	—
Clover	100-150	83
Chickpea	26-63	60-70

Guar	37-196	—
Cowpea	53-85	60
Groundnut	112-152	60
Lentil	35-100	18-30
Green Gram	50-55	30
Pigeonpea	68-200	20-49
Soybean	49-130	—
Peas	46	20-32
* Fenugreek	44	—
* Khesari	66	36-48
* Pillipesara	201	
* Dhaincha	86	
* Sunnhemp	91	

* Output in 45-60 days, used as green manure.

Gaur (1980) emphasized that more research work needs to be done on the survival of phosphate-solubilizing micro-organisms in carrier-based inoculants on the lines of Rhizobium inoculants. A carrier based preparation under the name 'Microphos' has been developed recently at the mocrobiology division, Indian Agriculture Research Institute, New Delhi.

Keeping these aspects of biofertilizers influencing the soil fertility and crop production the present studies related to Rhizobium, Azotobactriane and phosphobacterine have been incorporated and following objectives were taken up and investigations have been classified in the following three sub chapters of the experimental finding of the thesis.

First chapters of the thesis signifies the general introduction of the research topic in titled, 'Biofertilizer studies in soil and plant relationship'.

The second chapter of the thesis comprises a brief review of literature on the related subject relevant to the present work.

Third chapter of the thesis describes various methods of experimental techniques involved during the process of conducting the laboratory and field experimentation.

The fourth chapter imbodies the results obtained during the experimental work carried out in the present thesis and their interpretation and discussion the context of review of literature on the subjects. It includes graphic presentation, diagram illustration and statistical analytical explanation regarding the experimental findings. Following objectives have been discussed with their experimental observations :

(a) To find out the effect of Rhizobia inoculation with F.Y.M. and sludge applied as organic matter source alongwith M.R.P. on lentil (Lens esculenta moench) crop.

(b) Influence of Azotobactrine and Phosphobactrine and organic matter on wheat (Triticum aestivum) crop and compared with varying doses of N.P.K. fertilizers.

(c) The residual effect of field trial conducted in the experiment number (3) was also taken up to study its response on gram (Cicer arietinum) in the next year.

The fifth chapter deals with summary and conclusion related to the present research work.

In the last chapter a list of references arranged alphabetically indicating bibliography is included.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Numerous field and green house experiments have been reported in literature pertaining to the application of biofertilizers in crop production and their relationship with soil nutrient status and fertility. However in this chapter an interest is focussed to bring together the literature available on biofertilizers viz. Rhizobium, Azotobacter, Phosphobacterine cultures on different crops alongwith N.P.K. fertilizers.

The use of rhizobial cultures for ensuring root nodulation of leguminous crops has been advocated in many countries on a commercial scale, 'legume inoculant' are being produced and sold in U.S.A., Australia, New Zealand, India and other countries. The knowledge of the natural relationship between rhizobia and leguminous plants has had a broad development. Early investigators placed emphasis on the biochemical characteristics and other properties of the rhizobia as effective and ineffective agents. In contrast, the host plant was more or less relegated to the role of a more recipient of the microsymbiont, or at best a reflector of the reactions that took place. As out knowledge has enlarged, emphasis has gradually shifted towards the plant as the potentially dominant participant in the symbiotic complex. Two broad categories of this association invite continued research, one of these relates to the importance of symbiotic nitrogen fixation in agriculture and the other points to new vistas in methodology (Allen and Baldwin, 1954).

An efficient Rhizobium inoculant can save upto 80 percent of the crop's nitrogen requirement, provided the introduced efficient strains dominate the rhizosphere and profusely nodulate the roots of the crop (Subba Rao, 1978). In areas where nodulation of roots is adequate and the nodules have all the attributes for efficient functioning the need for rhizobium inoculation hardly

arises, as has been shown in extensive field survey on the rhizobium status for an Indian soil. (Sundara Rao *et al.*, 1972)

The most notable success has been in the inoculation of legumes with rhizobia, a practice which dates from the work of Hellriegel and Wilfarth in 1888. The inoculant superscribed with methods of using, direct application to seed or broadcasting and mixing of inoculum-blended soil with top layer of soil, was introduced by Nobbe and Hiltner in 1896. At that time farmer hand to depend upon the soil transfer system to successfully establish legumes because of unreliable inoculum produced by the laboratories. When properly applied, laboratory produced inoculating large number of viable effective rhizobia produced result in fields relatively free of rhizobia (Burton, 1979).

Gram (Cicer arietinum) being an indigenous crop of India, inoculation may not be imperative for its successful cultivation in all the Indian soils. But keeping in view the fact that naturally occurring rhizobium inhabiting a soil for a number of years gradually looses its efficiency with lapse of time (Manil and Brakel, 1965). Inoculation with efficient strain of Rhizobium seems desirable as it will establish better relation with the root zone of the crop in comparison with the indigenous strain. The reputed rhizobiologists like Allen and Allen (1981) and Vincent (1965) emphasized the need of inoculation in majority of the agricultural soils throughout the world. Moreover, inoculation of legumes with effective strains of rhizobia has been a major factor in improving their yield and quality (Erdman, 1953).

The necessity for selecting suitable strains of Rhizobium to bring about maximum benefit to leguminous crops has been widely realised throughout the world. In India, Rajagopalan (1938) observed that legumes inoculated with cultures of certain type of strains of bacteria from their nodules were for superior to the uninoculated ones. An increase of 17 to 131 percent in yield of Bengal gram (Cicer arietinum) was found due to inoculation in the pot-culture experiment (Sundara and Sen, 1969).

Gaur and Sen, (1975) reported that selecting the most efficient nitrogen fixing strain from among those belonging to the dominant soil group of a particular soil and using the strain in the soil which is dominated by rhizobial population of same soil group resulted in significant increase in yield (12 to 120 percent) in case of Bengal gram seed bacterization with Rhizobium caused increase in seed yield, dry matter accumulation and nodulation of Cicer arientinum plant (Tripathi *et al*, 1975). Ten strain of Gram Rhizobium were tested by Patil and Madhane (1974) who reported that increase in yield of gram (Cicer arietinum) due to seed inoculation with Rhizobium was in the range of 24 to 62 percent and it was significant.

In a field experiment, significant effect of rhizobial inoculation on nodulation was observed by Bhalla and Sen (1973). There was significant increase in the nitrogen content of plant due to seed inoculation with Rhizobium in case of red gram, Cow pea and horse gram while in case of green gram, there was as increase in nodulation and yield (Ramaswamin and Nair, 1965). Dorosinski and Kadyrav from the U.S.S.R. (1975) reported that active strain of Cicer Rhizobium increased the yield of aerial mass of cicer arietinum L. by 25-36 percent and protein content by 2-6 percent of the total content of nitrogen in the plant. Active strains of rhizobia, besides producing greater number of nodules of large size and fixing higher amount of nitrogen, caused an increase in proportion of protein and amount of amino acid in pea.

Isolutes of Cicer rhizobia were tested in sand culture in Leonard jars by Sanoria and Dube (1972). Slight isolates formed good nodules. Two of them (H_{44} and H_{45}) proved highly effective under field conditions and were used for the production of legume inoculant in modified to lignite carrier. It was reported by Vaishya and Sanoria (1972) that all the strains of Rhizobium isolated from Bengal gram exhibited a high degree of host specif city. Studies on the interaction between crop varieties and Rhizobium strains

revealed that strains H_{45} was superior to others with respect to root nodulation and effective index of all the five varieties examined.

Looking to the beneficial effect of seed inoculation with Rhizobium on improvement of soil fertility, legume quality and grain output search for new nitrogen fixation alongwith efficient genotypes of the legume species which possess the ideal root architecture and good 'root biomass' to nodulation late roots efficiently as well as profusely under field conditions is yet another approach so that fixation of atmospheric nitrogen and absorption of nature nutrients could be promoted at the same time. However, this is a never ending process.

It is well known that symbiotic bacteria improve the soil proporties, quality and quantity of legumes but a symbiotic organisms almost from the time that Azotobacter was first discovered by Beijerinck (1901) as a micro-organism capable of fixing free nitrogen. Statements have been made that this bactirium is closely associated with cultivated plants and inoculation of soil and plants (Voorhees and Lipman, 1907) may benefit both soil and plant. Result of Truffaunt and Bezssonoff (1924) further promoted the research with Azotobactor. Active work on non-symbiotic bacterial inoculant was initiated from 1932 onwards by a number of Soviet Scientists and 1942 Azotogen' a commercial preparation of A. Chroococum was used on five million area of crops. (Balls 1996). A number of experiments were conducted in some other countries also. Result of most of the later experiments were reviewed by Cooper (1959) and Mishustin and Naumova (1962). A momograph 'Azotobacter and its use in Agriculture by Rubenchik (1960), later translated from Russian into English in (1963), incorporated much information on the structure metobolism and ecological relationships of Azotobacter alongwith its use as bacterial fertilizer.

Thompson (1974) obtained significantly increased yield from wheat and barley, and yield components were highly influenced by Azotobacter

inoculation. Yield of paddy was increased more by application of Azotobacter than the application of 50 kgN/ha (Patil *et al*, 1976). Seed, seedling and soil inoculation with Azotobacter were reported to increase the growth and yield of many crops viz paddy, wheat, maize, sorghum, cotton, tobacco, sunflower and mustard, Sundara Rao *et al*, 1963; Rovira, 1963; Patel, 1969; Sanoria and Sundara Rao, 1975; Oblisami *et al*, 1976; Rangarajan and Muthu Krishnan, 1976). Inoculation with a Chroococcum resulted in increased paddy yield in presence of phosphate fertilizer or lime (Sulaiman, 1971) and significant increase of wheat yield when soil was basal dressed with $(NH_4)_2$ SO_4 and super phosphate (Sanoria and Sundara Rao, 1973-74) yield component of wheat and barley were highly and positively influenced by Azotobacter inoculation (Thompson, 1974). Yield of potato was more due to seed bacterization with Azotobacter and ammonium molybdate (Volodin, 1969). Soyabean responded better to inoculation (Radicin being more effective than Azotogen) than nitrogen fertilization on a lossses loam soil (Streuber, 1967). (Nair 1972) observed no significant increase in yield due to Azotobacter inoculation and yield of potato, tobacco and lettuce were not affected by Azotobacter though it remained in the rhizosphere throughout the growth period (Manil and Brakel, 1965).

Inoculation of legume seeds with cultures of root nodule and free living bacteria is a means of ensuring establishment of seedling in soil which lack the suitable bacteria. The main use of Azotobacter and Rhizobium in agriculture is in the form of 'azotobacterin' and 'nitrogin' respectively is important. Statements have been often made that Azotobacter inoculation of soil or seed is effective in increasing yield of crops in well manured soil with high organic matter content. Besides the ability to fix atmospheric nitrogen, this microorganism is also known to synthesize biologically active substances such as B-vitamins, indole acetic acid and gibberellins and has fungicide properties on certain pathogenic fungi. Due to these attributes

Azotobacter showed beneficial effect on seed germination, plant growth, plant stands and vegetative growth (Subba Rao, 1977).

Several experiments conducted in temperate regions of the world show than nitrogen fixation in Azotobacter inoculated soils is not more than 10 to 15 kg N/ha/Year, depending on the availability of carbon sources. Bacterial preparations containing Azotobacter cells under the name 'azotobacterine' are being produced and used in USSR and East European countries such as Czechoslovakia, Rumania, Poland, Bulgania and Hungary where bacterization of seeds with azotobacterin has proved beneficial in increasing yields of crops such as wheat, barley, maize sugarbeat, carrot, cabbage and potato. The increase in yield of field crops was not more than 12 percent over corresponding uninoculated control (Subba Rao, 1977).

Field experiments in India on different crops by seed or seedling inoculation with Azotobacter with or without basal dressing of organic and inorganic fertilizer revealed that yield increases due to inoculation are rather variable for different crops like wheat (Sundara Rao *et al*, 1963; rice (Mehrotra and Lehri, 1971), tomato (Mehrotra and Lehri, 1971).

In field condition the amount of nitrogen fixed by Azotobacter showed wide variation ranging from 10.0 to 60 kg/ha annually (Tzehapek and Garboksy, 1952; Pelozar and Reid, 1958; Paul *et al* 1971) Presence of soil extract in addition to glucose or sucrose or mannitol in liquid both, enhances the efficiency and amount of fixed nitrogen (Sundara Rao and Iswaran, 1959) clay being superior to clay and sand and sand + humified saw dust. Though beneficial effect of Azotobacter due to its nitrogen fixing ability has often been criticized (Sinha, 1958, Alexander, 1977) yet the possibility of beneficial effect arising out of this ability cannot be ignored. The fix nitrogen is later made available for use of higher plants. (Sheloumova, 1941).

Kleckzkowska (1945) found that Azotobacter treatment of oat and wheat seeds increased the nitrogen content of grain and straw. Nitrogen assimilation by plant due to Azotobacter treatment being 34.2 to 37.5 percent higher than that by control plant. Root treatment of tomato seedlings with Azotobacter vine landi and Azotobacter beijer, iniki accelerated plant growth and increased the fruit yield (Rosario and Barea, 1975).

Rao and Sharma (1981) carried out an experiment with two strains of a chroococcum on four varieties of wheat. They also reported that the effect of inoculation on tomato increased with decreased application of mineral nitrogen. Application of nitrogen inhibited the proliferation of a chroococcum in the rhizosphere of tomato.

Azotobacter inoculation led to an increase in protein content of vegetable crops. (Seigel and Schmidt, 1966) and increased not only the nitrogen content of grain and straw but also the nitrogen assimilation by oat and barley plants (Krasilinikov 1958). Azotobacter was effective in increasing significantly the N content of wheat grains when the soil was basal dressed with ammonium sulphate and super phosphate (Sanoria and Rao, 1973-74).

Insoluble inorganic compounds of phosphorus are largely unavailable to plants and the transformation of available form of applied phosphorus to unavailable form is a major problem in the present intensive agriculture, in relation to lphosphate fertilization programme, but fortunately many micro organisms can bring the unavailable phosphate into solution (Sundara Rao and Sinha, 1963; Subba Rao and Bajpai, 1965; Paul, 1966, Taha *et al*, 1969; Gaur *et al* , 1973). The phosphate dissolving bacteria play an important role in supply the growing plants with their needs of phosphorus and therefore, may be considered to function of plant nutrient factory right at the farm.

Effectiveness of phosphobacterin on growth and yield of crops has been reported from Russia and its use is also popular in Russian agriculture. Most of the workers in other parts of the world on this subject reported negative response which has been altributed largely due to the use of unsuitable cultures. The use of phosphobacterin culture in legumes seems to have been started in the recent part and as such the information in this respect seems to be meagre.

Sundara Rao (1965) reviewed the results of field trials conducted with phosphobacterin inoculation in wheat, berseem, maize, black gram and rice in different parts of the country. He reported that in 10 out of 18 experiments, phosphobacterin inoculation showed beneficial effect on the yield. On the other hand, Rana *et al* (1975) and Swaby and Sperber (1958) did not find significant effect of phosphobacterin on grain and straw yields of wheat and green gram.

Shah (1959) reported 20 percent increase in berseem fodder yield due to phosphobacterine inoculation, marked increase in the dry matter accumulation and yield of cow pea was observed by Bajpai and Sundara Rao (1971).

Gerresten (1948) reported that CO_2 produced by micro organisms in the rhizosphere seemed to be effective mechanism in increasing the availability of phosphorus and its uptake by plants. Sperber (1957) suggested that phosphorus was released in soil from inorganic compound due to local accumulation of lactic acid and action of H_2S produced by micro organisms particularly under anaerobic conditions. Sen and Paul (1957) claimed that the lactic acid and H_2S developed by microbial metabolism were at least the two biological product important in rendering insoluble phosphate into available form.

In a green house trial with pea (Pisum sativum) Yoasry *et al* (1978) reported that phosphobacterin inoculation increased plant dry matter yield by 10.9 percent, compared with uninoculated control. Pikovskaya (1948) obtained an increase in green matter yield in oat plants due to the inoculation of 'Bacterium P'. According to Shestakova (1963) agneous formulation of phosphobacterin increased lime and pine weight and their intensive growth period by 22-25 percent and 16-19 percent respectively.

That phosphobacterin inoculation caused a decrease in soil pH due to the formation of organic acid (Sundara Rao and Sinha, 1963) supports the view that CO_2, H_2S and acid end product of microbial activities affect the solubilization of phosphate. However, Rana *et al* (1975) did not find any beneficial effect of phosphobacterin inoculation of wheat on the available phosphorus content of the soil.

Of the three major mineral nutrient elements, phosphorus plays both direct and indirect role in the metabolism of plants and micro organism its major physiological role being in certain essential steps in the accumulation and release of energy during cellular metabolism. Researches over the years have clearly shown that phosphorus is essential for various activities in living cell. Deficiency of phosphorus causes disturbances in one or more vital plant processes including visual symptoms of disorder. The subject has been ably reviewed by Stewart and Williams (1942).

It is universally accepted that vegetative growth of legume is improved by the application of phosphate fertilizers (Thornton, 1956). The supply of phosphorus particularly at every stage of crop growth is essential for most of the legumes (williams, (1936) and in the absence of phosphorus growth of the legumes remains retarded (Stilt, 1944) with stunted root system (Olson and Freid, 1957). Phosphorus application has been found to increase dry weight as well as elongation of root mass in pea. (Volodin 1969). They also

observed more vigorous growth and improvement in branching with increasing level of phosphorus. Similar observations were recorded by Shiel *et al* (1970) and Svoboda (1974) in case of pea.

In trial with gram (Cicer arietinum) on sandy clay loam soil (pH 8.1) increasing the P_2O_5 rates from 0 to 25 and 50 kg/ha increased root length and weight. Sinha (1971) recorded increased dry weight of check pea with the application of 60 kg P_2O_5 /ha. Similar response of phosphorus on dry weight of pea was reported by Tyagin *et al* (1972). Countrary to this Sahu (1973) could not get response of legumes to phosphorus application in respect of dry matter accumulation.

Phosphorus stimulation none through its effect on Rhizobium than on the hostplant. In the absence of phosphate bacterial function of legume roots remained latent and resulted in poor development of nodules. Valauthan (1947) observed increase in bacterial activity with phosphorus application in check pea. Singh (1971) observed that number and dry weight of nodules in check pea increased significantly upto 67.5 kg P_2O_5/ha under Varanasi (U.P.) condition progressive increases in the values of these characters were noted upto 100 days after sowing followed by gradual derease there after due to degeneration of nodules.

Chowdhary *et al.* (1979) observed variable response to phosphorus application in two seperate experiments at I.A.R.I. New Delhi. Phosphatic fertilizer applied in the range of 33.3 to 100 kg P_2O_5/ha either alone or in combination with 30 kgN did not result in significant variation in respect of grain yield increased significantly by application of 20kg N + 25kg P_2O_5/ha over control, when only 20kg P_2O_5/ha was available in the soil. The yield decreased with increasing phosphorus level without increasing nitrogen.

Singh *et al* (1972) studied the response of chick pea to nitrogen and phosphorus fertilization under different crop rotations on sandy loam soil of

Hissar and found an increase in grain yield due to application of 40kg P_2O_5/ha over the control. Rathi and Singh (1976) working on loamy soils of medium fertility at Meerut (U.P.) reported increase in grain yield of chick pea Va T_3 up to 75kg P_2O_5/ha. Similarly Singh (1971) working on loamy soil of Varanasi (U.P.) recorded a conspicuous increases in grain yield over control due to application of varying level of phosphorus from 22.5 to 67.5kg P_2O_5/ha. According to Singh *et al* (1978) 80kg P_2O_5/ha gave higher yield and further addition of 15 to 30kg P_2O_5/ha gave no further yield increase.

Phosphorus has been proved to improve the quality of the produce in general but of legumes in particular. Phosphorus is known to increase the protein content of legumes. Shiel *et al* (1970) and Sosulski *et al* (1974) also observed increase in the protein content of seeds due to phosphorus fertilization Radakov (1972) also noticed the effect of super phosphate on protein content of chick pea. Ravankar and Badhe (1975) observed that the application of phosphate signi ficantly increased the values of protein fat and mineral matter in black gram.

Lendi and Gomez (1980) in experiments that study the influence of nitrates on the growth and symbiotic nitrogen fixation in bean (Phaseolus vulgaris) plant reported that 14 day old seedlings of P. vulgaris. Contender were grown in nutrient with or without inoculation with Rhizobium at 4 N rates. Root shoot and leaf dry weight increased with age and with N rates, only in roots was dry wt. Lower in inoculated than in uninoculated treatments N, P, K, Ca and mg contents of the root, shoot and leaves are given.

Pagaduan (1980) in experiments that liming, Phosphorus, inoculation and pelleting studies on winged bean grown in some Philippine soil had reported winged bean (Psophocarpus tetragonolobus) CV. TPT-2 grown in pots on 5 soils with a range of pH from 4.8 to 7.7 and given the equivalent of

0 or 30 kg N/ha, 0 or 60 kg P_2O_5/ha and lime and Rhizobium inoculum in all combinations. DM yield and pod yield were increased by addition of CaO + P + N on inoculation on the 3 acid soils but were depressed on the Faraon clay loam (pH 7.7). Nodulation was greatest on the maahas clay loam (pH 6.7) and increased by inoculation and CaO and P application on all soils. N uptake increased with increasing soil pH; fertilizers had different effects on the different soils. N uptake was max. (125.89 mg) on the Faraon clay loam on treatment. Pod CP content was not affected by any treatment.

Mallik and Sanoria (1980) in experiment with effect of rhizobial isolates from pea group hosts on lentil (Lens esculenta) in the same soil in pots and field reported that effects of lentil seed inoculation with 3 Rhizobium leguminosarum strains from lentil, 4 strains from Lathyrus sativas and 6 from pea on nodulation and seed yield of lentil grown in the same soil in pots and in the field are described.

Sanoria and Mallik (1981) in experiment on the effect of seed inoculation with Rhizobium and Azotobacter on yield and quality of lentils (Lens esculenta) reported that in trials during 2 seasons, 3 Rhizobium leguminosarum and 2 Azotobacter isolates were used singly or in mixtures to inoculate lentil seeds. R-leguminosarum strain F_2 and Azotobacter strain B_4 gave the highest lentil seed and straw yields of 1.9 and 3.06 t/ha. Seed CP contents ranged from 18.0% to 21.6% with Azotobacter strain B_5.

Sharma, Chahal and Rowari (1982) in experiment with studies on relationship between chlorophyll content and nitrogen fixation in lentil (Lens esculents L.) nodulated by different strains of Rhizobium leguminosarum reported that inoculation of lentil seed with 8 R-leguminosarum strains increased the leaf chlorophyll and nodule leghaemoglobin contents, strain SU-56 being the most efficient. These contents were positively correlated with nodule dry wt., DM and seed yields and total N uptake plant.

Selim *et al*, (1985) in experiment on yield response of pea (Pisium Sativum) to NPK fertilization and to inoculation with rhizobia in a sandy soil have been reported in a field experiment in the Kalabsha valley, application of 60 kg N/feddan or seed inoculation with a local inoculum (okadin) or an introduced in oculum (TAL) increased FW and OW of pea plants. N uptake and green pod yield. 60 kg N/feddan + TAL, increased seed yields. Application of 400 kg potassium superphosphate/feddan in addition to inoculation increased green pod yield, seed, P content and protein percentage and the increases were greater with TAL than with Okadin. 1 feddan equals to 0.42 ha.

Kalyan Singh, *et al*, (1986) in experiment on effect of phosphorus and biofertilizer on growth parameters of lentil have reported effect of P-Rhizobium inoculation and phosphobactrin on LAI, NAR, CGR relative leaf growth rate and DM accumulation in lentils are described.

Poi, Ghosh *et al* ; (1986) in experiments on response to lentil (Lens esculenta) and chickling pea (Lathyrus Sativus) to inoculation with different strains of Rhizobium leguminosarum have reported in field trials, seed inoculation with R-leguminosarum strains L25 and L20 increased nodulation and plant N content and increased seed yield by 59.23 and 29.38% in lentils and 38.87 and 17.41% in L. Sativus, resp.; inoculation with other strains was less effective.

Pereira and Boiss (1987) in experiment with the effeciency of the alumina system for differentiating between been (Phaseolus vulgarish) genotypes for growth at different levels of phosphorus availability was determined. In addition to response to P levels, comparisons were made between plants receiving N either from fertilizer or nitrogen fixation. When the CV Corioca was provided with either 100 ppm of N or inoculated with Rhizobium leguminosarum biovar phaseoli, differences in shoot dry weight

and nodule number were related to P level. There was a greater proportion of green, ineffective VS red, active nodules at the low P concentration than at the high P concentration. In a second experiment two CVS. Puebla 152 and carioca and the breeding line CW 24.21, either were inoculated with Rhizobia or provided with 150 ppm of N. Each genotype-nitrogen combination was grown at 8 levels of P. There was a positive effect of P level on shoot dry weight, nodule number and nodule mass. Root mass was affected less than nodule or shoot mass by the P level of the growth medium. Nodule mass but not P concentration in the nodules, was affecting by P levels, whereas in the other plant tissues, P-concentrations were lower at lower P levels in the media.

Chandra, Rajput *et al* ; (1987) in experiment on effect of N, P4 Rhizo inoculation on growth & yield (French Been) have reported plant growth and yield (46.19-71.39 q/ha) increased with increasing N(0-50 kg/ha) and P_2O_5 (0-80 kg/ha) rates and with seed inoculation with Rhizobium.

Kumar, Malik and Ahmad (1988) in experiment effect of mixed culture inoculation of Rhizobium and Azotobacter on yield, nutrient uptake, and quality of lentil in calcareous saline soil have been reported in field trials the effects of inoculation of Lens culinaris seeds with 3 Rhizobium leguminosarum strains and/or 2 Azotobacter chroococcum strains were investigated at 30 and 60 cl after sowing (DAS). Generaly seed inoculation did not increase number of nodules/plant at 30 or 60 DAS (except with Rhizobium BK4 alone) but nodule DW/plant was increased with all inoculants except Rhizobium BP5 alone. Inoculation with Rhizobium BK4 + Azotobacter AD increased straw and seed yields by 26 and 43% above the uninoculated control and by 23 and 15% above yields after Rhizobium BK4 inoculation alone. The highest seed protein content and N uptake into seed and seed + straw resulted after inoculation with Rhizobium BK4 alone or in combination with Azotobacter was the best inoculant.

Jain, Joshi and Taneja (1988) in experiments on effect of phosphorus and rhizobium cultures on protein and gum content of cluster-bean [cyamopsis tetragonoloba (L) Taub] have reported the application of 20 kg P_2O_5/ha to C. tetra gonoloba increased both the gum and proein content in seed inoculation or 40-60 kg P_2O_5 increased the protein content but decreased the gum contents.

Bandyopadhyay (1988) in experiment with variation in host and bacteria in the nodulation of phaseolus species reported seeds of 8 varieties of P-vulgaris were sown and inoculated separately with 13 strains of Rhizobium phaseoli. Seeds of 2 varieties of P-aureus (Vigna radiata). 2 of P-mungo [V-Mungo] and one of P-frilobus [V.aconitifolia] ever inoculated seperately with 10 different strains of cowpea Rhizobium. At flowering nodules were harvested and fresh weight measured. From analysis of variance of number of nodules and nodule fresh weight it was found that both host variety and bacterial strain produced significant effect on the above 2 characters.

Gupta and Sharma (1989) in experiment with interactive effect of Rhizobium and Phosphorus on nodulation crop yield and nitrogen fixation in lentil (Lens culinaris M.) have reported in field trials in the rabi (winter) season of 1985-86 on sandy loam soil. Nodulation and N-fixation of lentils given 0, 8.16, 24 or 32 kg P/ha and seed inoculation with Rhizobium or no inoculation were studied 30, 60 or 90 days after sowing. The highest nodule number and nodule DM/plant were found at 60 d after sowing with inoculation and P application, seed yield was 0.87 - 1.30 f/ha with 0.32 kg P and no inoculation and 0.89 - 1.68 t with 0 - 32 kg P and inoculation. Seed protein content increased with P application and inoculation. N fixation ranged from 0.41 mg N/Plant per day at 30 d after sowing with no por inoculation to 1.25 mg/plant at 60 d after sowing, with 32 kg P and inoculation.

Singh and Singh (1989) in experiment on effect of nitrogen, phosphorus and seeding rates on growth yield and quality of guar and rainfed conditions have observed in 1981-82, cyampsis tetragnoloba gave av. seed yields of 1.89, 1.54 and 1.90 t/ha with seed inoculation with Rhizobium Japonicum, 20 kg N/ha and inoculation + N + resp.; compared with 1.42 t in the untreated control yields were 1.39, 1.69 and 1.92 t with 0, 30 and 60 kg P_2O_5/ha resp., and 1.41, 1.68 and 1.91 t with sowing rates of 10, 20 and 30 kg/ha, resp. effects of the inoculation and/or N and P treatments on nodulation, root DW. Seed wt/plant, seed protein and gum contents, 1000 - Seed wt. water use efficiency and net returns were similar to those on yields.

Singh and Singh (1990) in experiments on uptake of nitrogen, phosphorus and potassium by guar (Cyamopsis tetragonoloba) (L., Talib) as influenced by nitrogen (with and without seed inoculation) phosphorus and seeding rates under rainfed conditions reported that in 2 year trials (1981 - 82) with C. tetragonoloba, seed inoculation with and uptake in seeds and straw, followed by seed inoculation and N. Increasing P_2O_5 rates (0, 30 and 60 kg/ha) increased both contents and uptake of N, P and K. Effects of sowing rates (10, 20 and 30 kg seeds/ha), on nutrient contents and uptake were in consistent in the 2 years.

Sidorova, Simakov and Stolyarov (1990) in experiment on evaluation of pea varieties for nitrogen-fixing activity reported that there were marked intervarietal difference in N fixation activity between 13 high-yielding varieties in pot tests using seeds inoculated with Rhizobium leguminosarum strain 250 N fixation per plant was 0.09-18.35/g N/ha when mineral N was applied and 43.49-123.45/g N/ha when it was not use of N fertilizers caused a considerable fall in N fixing activity, especially in Neosypayuschisya and Touzhenik, which appreciably exceeded other varieties in N fixing activity when No N fertilizer was applied. An increase in growth period duration,

number of fertile nodes per stem/seed yield and plant height was associated with increased N fixing activity and these triats could be used as criteria for selecting lines for high N fixing activity.

Bell, Edwards and Asher (1990) in experiment on growth and nodulation of tropical food legume in dilutes solution culture reported that twenty-two tropical food legumes were grown in dilute nutrient solution with or without rhizobium inoculation (Bradyrhizobium japonicum in Soyabeans, Rhizobium leguminosaram in chick peas, R-legumiso sarum biovar phaseoli in phaseolus vulgaris CV. Gallary and Bradyrhizobium spp. in all other species) and supplied with either low adequate amounts of inorganic N-Growth of legumes supplied with adequate inorganic N was generally satisfactory. However the solution P concn (15/M) was excessive for vigna mungo, while the initial solution mn concn (1.8/M) was excessive for V. radiata Growth responses to inoculation with rhizobium at low inorganic N supply were obtained in only 9 of the 22 legumes studied, and shoot DM yields were S 51% of those obtained with adequate N supply. Poor growth by inoculated plants with a low N supply was attributed to failure of the inoculated strain of Bradyrhizobium to infect roots in phaseous lunatus and Pachyrhizus erosus, to low nodule numbers in V. vadiata, V. mungo and P. Vulgaris CV. Gadl Groy, or to excessive P uptake in V. Vita 4 and/or Mn uptake in V. mungo and V. radiata. High solution temp. could have limited N fixation by some of the legumes particularly chick peas.

Saber and Kabesh (1990) have observed in a green house pot experiment lentils CV. Giza 9 seed inoculated with rhizobium legumino sarum were given 15, 100, 200 or 400 kg rock phosphate/fedden with or without a 1.1 mixture of elemental S and rock phosphate and with and with or without a 1.1 mixture phosphate dissolving bacteria plant DW and N, P, Fl, Zn, Mn and Cu uptake increased with rock phosphate, sand phosphate

dissolving bacteria compared with the untreated control. DM yield and nutrient uptake were slightly higher with S application than phosphate-dissolving bacteria.

Parthiban and Thamburaj (1991) in experiment on influence of rhizobium culture and nitrogen fertilization on French Beans have observed in trials with the [Phaseolus vulgaris] cultivate Premjer, under partia] irrigation the plants received N at 0.25, 50, 75 or 100 kg/ha + P at 100 kg/ha and k at 50 kg/ha rhizobium sp. culture inoculation. The number of days to 50% flowering was increased by hight N rates, from 38 days in controls without any fertilizer or inoculum to 48 days at the highest N rates. The highest yield of green (21.46 t/ha) was obtained with 50 kg N/ha Rhizobium inoculation.

Chandra (1991) in experiment on influence of different levels of Rhizobium inoculum and phosphorus on nodulation, dry matter production and yield of lentil observed in field trials in 1987-90 al Nayina, Uttar Pradesh, lentils v. PL 406 gave seed yields of 1.05, 1.16 1.29 and 1.24 t/ha with no inoculation and seed inoculation with 5, 50 or 100 g Rhizobium inoculum/kg seed, respectively, and 1.03, 1.19 and 1.33/ha with application of 0, 20, and 40 kg P_2O_5/ha respectively inoculation increased nodule number and DW in 2 out of 3 years and P application increased nodule number only in 2 out of 3 years.

Azad (1991) in response of phosphorus and Rhizobium culture on grain yield of lentil observed in field trials at 3 beation in Gurdashpur district Indian Punjab in 1986-87 Lens Culinaris CV. L 9-12 was inoculated or not inoculated with Rhizobium and given 0, 20, 40, or 60 kg p/ha. Grain yield was increased by P irrespective of Rhizobium inoculation. Rhizobium inoculation increased mean yield over uninoculated controls at all levels of P application. Highest yield (1.56 t/ha) was with 60 kg. P/ha and Rhizobium

inoculation. Yield ranged from 0.8 t without P to 1.39 t with 60 kg P without Rhizobium inoculation and form 1.06 to 1.56 t with Rhizobium.

Roy and Rohaman (1992) on effect of seed rate and inoculation on nodulation, growth and yield of lentil have observed fully replicated randomized field trials were run during the winter seasons of 1989-90 and 1990-91 at Joydebupur Bangladesh on clay loam soil. Two lentil cultivars were grown (lintil-5 and L-81124) under 3 sowing rates (10, 20, and 30 kg seed/ha) and 3 inoculation treatment (now, inoculation with Rhizobium strain RLC-140 and inoculation + 20 kg N/ha at sowing). For both species LAI and DM increased with increasing sowing rate but the number of nodules/plant fill. Lentil-5 produced more nodules/plant and had higher CAI and seed yields but L-81124 produced more DM. Seed yield increased linearly with increasing sowing rate with inoculation and with N application. Apparent harvest index was influenced only by sowing rate.

Yanni (1992) in performance of chick pea; Lintil and Lupin nodulated with indigenous or inoculated Rhizobia micropartners under nitrogen boron, cobalt and molybdenum fertilization schedules observed chick peas, lentils and lupinus albus grown in pots were soil inoculated with Rhizobium loti, R. legumino surum biovar areas and Bradyrhizobium sp., respectively with or without 30 or 60 ppm. N. Plant were also given 3 ppm. Mo, 2 ppm. CO_2 + or 1 ppm. - B or no trace elements. Nodulation plant DW and seed yield where increased by inoculation. Nodulation in chick peas and L. albus was decreased. But seed yield increased by 60 ppm. compared with 30 ppm. N. The effects of trace elements on inoculation and seed yield varied with species, N rate and inoculation treatment results are tabulated. Seed yield was generally highest in plant given Mo.

Csizinszlay (1992) on growth and nutrient accumulation of winged been, Psophocarpus tetragonolobus (L.) DC. Seedlings with seed inoculum

and various nitrogen sources observed P. tetragonolobus strain Tpt-1 seedling from non-treated seeds or seeds inoculated with the cow pea strain of Rhizobium sp. were grown in a greenhouse, with 4 N treatments (100/% NO_3, 70% NO_3,; 30% NH_4 50% NO_3; 50 % NH_4 and 100% Urea). Plant height were measured weekly and numbers of tritaliate leves where counted from 3 weeks after sowing. Shoots were cut off 6 week after sowing and BW. was recorded. Shoots were then dried at 60% C and their DW contents of N, P and other elements were determined. Root DW and element content were also determined. After 45% days roots nodules were most numerous with inoculum and 50% NO_3; 50 % NH_4 - N, and Zn concentrations in shoots and Mo concentration in root were higher with then without inoculum. Plants were tallest and number of trifoliate leaves greatest with the 70% NO_3; 30% NH_4 - N treatment plant height number of trifoliate leaves. Urea reduced plant height, Number of trifoliate leaves and shoots and root DW. seedlings from non-inoculated seeds required a 70 : 30 ratio of NO_3 : NH_4 - N for optimum growth and development.

Kumar and Agarwal (1993) in experiment on response of lentil to Rhizobium inoculation, Nitrogen and Phosphorus fertilization observed in a field trial in the winter season of 1989-90 on loam soil at Gurukel - Narsan. Uttar Pradesh lentils CU. T. 36 were inoculated with Rhizobium or not inoculated and were given 0 or 20 kg N/ha and 35-100 kg P_2O_5/ha. Seed yield was increased from significantly different between inoculation treatments (2.03-2.29 t/ha in year 1 and 1.77-1.87 t in year 2) or between P treatment in year 2 but ranged significantly from 2.15 t with no P to 2.25 to with 40 kg P_2O_5 in year 1 and there was a significant interaction between inoculation and P rate in year 1 only.

Katyal, Venkateswarlu and Das (1994) in experiment with biofertilizer for nutrient supplementation in dryland agriculture. Potentials and problem have observed the potential and limitation of Biofertilizers (BF) reviewed.

Past research has shown a general inconsistent response pattern to biofertilizer treatment of dryland crops. Key factors contributing to the inconsistent performance of BF in drylands are highlighted. Some specific suggestions on future areas of research to optimize the response to BF in dryland agriculture are presented.

Fernandez and Felips (1994) in experiment on essentiality of boron for symbiotic denitrogen fixation in pea (Pisum Sativum) rhizobium nodules have observed the effect of B deficiency on symbiotic Nitrogen fixation in pea CV. Argona was studies. In the absence of B the number, size and weight of nodules decreased and nodules development changed leading to an inhibition of nitrogenous activity. Examination of B-deficiant nodules showed dramatic change in cell walls and in both peribacteroid and intertion thread membranes. Suggesting a rate for B in the stability of these structures. It is concluded that B is required for normal development and function of nodules.

Hegle and Dwivedi (1994) in experiment with crop response to biofertilizer in irrigated areas have observed biofertilizers have an importence rate to play in improving nutrient supplies and their crop availability. They are of Particular significance in intensively cultivated irrigated areas where in a wide demand-supply gap of plant nutrients exists for very high nutrient turn-over in the soil plant system. Experiment conducted under All India coordinated Agronomy Research Project and other programmes in different crops and agroecologies have proved the potentiality of biofertilizer as a importent ingredient of integrated plant nutrient supply systems. However, the experimental results clearly indicate that the crops responses to biofertilizer are highly inconsistent and unpredictable, thus emphasising the need for refinement in biofertilizer production, distribution and use techniques at both research and development fronts. The present article in confined to a critical review of the performance

of different biofertilizer under actual field conditions in irrigated areas. Some important areas for future research to improve the agronomic efficiency of biofertilizer are also indicated.

Laura, Raj and Sangwan (1994) in experiment on effect of inorganic organic and biofertilizer on pearl millet yields in dryland areas have observed Pearl millet [Pemisstum glaucum] CV. HHB-67 was grown in plots on a sandy loam soil from 1988 to 1991 to evaluate the effect of 0, 10, 20 or 40 kg N/ha, 0, 2, 4 t FYM/ha and biofertilizer (control, seed inoculation with Azotobacter, seed inoculated with Azospirillum) on yield. The grain yields increased with all N rates up to 40 kg N/ha. FYM increased yields in 3 of 4 study years. Seed inoculation only increased yields by up to 0.22 t/ha as soil temperatures were lower then optimum for the microbes used.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Field Experiment

(i) Experimental Sites :

The sites for field trial was experimental farm of the Sheila Dhar Institute of Soil Science which is located near Mumfordganj at Allahabad. It is irrigated by tubewell water supplied by the Jal Sansthan, Allahabad.

The first, second and third field experiments were conducted in the year 1996-97, 1997-98 and 1998-99, respectively.

(ii) Field and their Cropping History :

All the experiments were conducted in well levelled square fields with necessary facilities of irrigation. The cropping history of the fields for the preceding three years is given in the following table : -

Table - A : Field trial conducted in experimental plots at SDI of Soil Science Research farm from 1993-96

Year	Khrif Crops	Rabi Crops
1993-94	Fallow	Wheat
1994-95	Paddy	Gram
1995-96	Fallow	Potato

Table - B : Field experiments conducted in experimental plots during 1996-99

Year	Khrif Crops	Rabi Crops
1996-97	Fallow	Lentil (Test crop) Lens esculenta moench
1997-98	Fallow	Wheat (Test crop) Triticum aestivum
1998-99	Fallow	Gram (Test crop) Cicer arietinum

IX. Climatic Condition :

The climatic condition of Allahabad is known for its cold winters and almost intolerable summers. However, the rainy season is pleasent. The average rainfall is about 80° - 100° cms and the average temperature varied from 32.4 to 40.0 °C with mean humidity of about 64 percent.

V. Layout :

Randomized Block Design was followed in all the experiments with 17 treatments having 3 replications in plots of 1×1 m^2 in the first, second and third field experiments.

In general, Rhizobial combination with F.Y.M., sludge and rock phosphate was studied in the first experiment. The second experiment was conducted with Azotobacter and phosphobactrine combination with the N.P.K., sluge and F.Y.M. The third experiment was conducted to study the residual effect of the various treatments.

Basal Dressing :

Before sowing, each plot was basal dressed with 1.25 Kg F.Y.M., 1.25 Kg sludge (12.5 ton/ha) respectively according to the treatments. Additional dose of phosphate at the rate of 50 kg. P_2O_5 as MRP/ha was simultaneously applied according to the treatment. The required quantities of the fertilisers were mixed well for each plot and the mixture was placed in the opened furrows as uniformly as possible by hands. Then it was lightly covered with loose soil in order to avoid direct contact of the inoculated seeds with the fertilizers.

In the second experiment plot was basal dressed with the required quantity of Urea, Rock Phosphate and Muriate of Potash with F.Y.M., Sludge, Biofertilizers viz. Azotobacter and Phosphobactrine cultures were processed for seed test and applied by broadcasting followed by mixing it well with a spade.

VII. Sowing and Harvesting :

Good viable seeds of Lentil (Lensesculenta moench) variety Type - 8 were sown 40 kg/ha in furrow. The second experiment on wheat (Triticum aestivum) variety 'Sonalika' was sown 125 kg/ha in furrows and the third experiment on Gram (Cicer arietinum) variety type-1 was sown 40 Kg/ha in furrows opened with the help of Kudal. To avoid contamination of cultures different beakers were used for different treatments. After sowing the seeds in the furrows they were immediately covered lightly with soil to promote germination. Bundles of the harvest of individual plots were allowed to dry in sunlight for few days and then weighed for dry matter yield. The difference of the dry matter yield and the grain yield plotwise was recorded as straw yield.

3.2 Bacterial Cultures for Seed Treatment

(i) Cultures used

The following cultures were used

Rhizobium leguminosarum

Azotobacterin

Phosphobacterin

The cultures obtained (*Rhizobium*) from Market of Khuldabad at Allahabad and *Azotobacterin* and *phosphobacterin* were obtained from Motilal Nehru Farmer Training Centre IFFCO, Phulpur Unit at Allahabad.

IV. Preparation of Sticker Solution :

The solution was prepared by boiling about 1 litre of water for about 15 minutes and then kept for some time for its cooling to avoid any contamination.

V. Procedure for Seed Inoculation :

Just before sowing for treating separately plotwise seeds were kept in beaker required to be sown in each plot. The beaker was repeatedly shaken for good adherence of bacterial cells on the surface of each seed after a little drying, the bacterized seeds were sown in furrows by hand as uniformly as possible.

3.3 Agronomic Management

Few days before sowing, the fields were irrigated to maintain optimum moisture status in all plots. The timing schedule for the management operations including sowing and harvesting was as follows :

Operation		Ist Experiment	IInd Experiment	IIIrd Experiment
Sowing		20-11-1996	4-12-1997	15-11-1998
Irrigation	I	3-1-1997	24-12-1997	28-12-1998
	II	15-2-1997	20-1-1998	25-1-1999
	III		15-2-1998	
	IV		5-3-1998	
	V		30-3-1998	
Weeding	I	(20-22)-12-96	(20-22)-1-1998	(5-10)-1-1999
	II	(25-30)-1-96	(5-7)-2-1998	
Harvesting		18-3-1997	10-4-1998	25-3-1999

3.4 Preparation of Soil Sample for Analysis

The representative samples about 1.0 kg of each plots were brought to the laboratory and air dried in shade. Wooden hammer was used for crushing the clods. After thorough mixing they were ground and then passed through 2 mm sieve. The unsieved particles were again and again crushed thoroughly,

mixed and finally passed through the same sieve. The soil sample thus prepared were kept in the same polythene bags and staked in the soil racks for analysis.

Methods Employed for Soil and Plant Analysis

3.4 Soil Analysis

I. Mechanical Analysis

Mechanical analysis was done by international pipette method as out lined by piper (1963).

II. pH (1 : 2.5 Soil-Water Suspension) :

pH value was measured with the help of Systonic Digital pH Meter 335.

III. Electrical Conductivity :

Electrical conductivity (dsm^{-1} at 25 °C) of saturation extract was determined with the help of conductivity bridge as outlined by Jackson (1973)

IV. Organic Carbon and Organic Matter :

The Organic Carbon and Organic Matter was determined by the modified Walkley and Blacks rapid filtration method (Piper 1963) in which a known amount of the soil was digested with potassium dichromate and sulphuric acid. The excess of chromic acid was back titraled with standard ferrous ammonium sulphate.

V. Cation Exchange Capacity :

Cation exchange capacity was determined by the method described by Jackson (1973).

VI. Total and Available Nitrogen :

Total nitrogen was estimated by micro Kjeldal/method and available nitrogen was estimated by the method as described by Jackson (1973).

VII. Available Phosphorus :

Available phosphorus was estimated Olsen's method using spectrophotometer (Kanwar and Chopra, 1976).

VIII. Potassium :

Potassium of soil was estimated by the method as described by Jackson (1973).

3.5. Plant Analysis

5 g of oven dried plant material was taken in a 100 ml, of tri-acid mixture made from 750 ml of Conc HNO_3, 150 ml of Conc H_2SO_4 and 300 ml of 60% per chloric acid was adopted. The content was heated on a hot plate at low heat for several minutes and then the temperature was increased. Heating was done till the H_2SO_4 evolved. The volume was then reduced to about 3 to 5 ml but not allowed to dry. Then distilled water was added to the beaker and contents filtered through on acid washed filter paper into a volumetric flask and volume was made up with distilled water.

Analysis of Plant and Nodule Samples

3.5 (I) Nitrogen :

Nitrogen was determined spectrophotometrically as described by Nicholas and Nelsen (1957) with slight modification of Nessler's reagent (Dissolved 22-72 g. of $HgCl_2$ in approximately 35 ml of solution containing 18.26g KI. The potassium mercuric-iodide was slowly added to 950 ml of NaOH solution containing 40 g of NaOH with constant stirring. Cooled solution was made upto one litre.

Each of the samples weighed to 1 g was taken in a digestion tube and 2 ml Conc. H_2SO_4 (A.R.) was added Warming the tube gently on a hot plate, 2 ml of H_2O_2 was added to each tube and they were kept for over night. On the next day, heating the tubes one by one alongwith dropwise addition of H_2O_2 and the digestion was continued till the digest became colourless. A blank digestion was also carried out without adding plant or nodule sample. The digested material, after making up its volume to 100 ml, was used for nitrogen estimation.

One ml of aliquot was taken in a .50 ml volumetric flask. After neutralizing it with 2 N NaOH, 1 ml Nessler's reagent was added and the volume was made up to the mark. The colour intensity was measured at 535 nm with a spectrophotometer. The sample reading was then compared against the reading of standard curve which was prepared by using different concentrations of $(NH_4)_2$ SO_4 solution (Dissolved 0.4712 g of pure dry ammonium sulphate in water and added 5 ml H_2SO_4 to avoid bacterial action. The solution was diluted to 100 ml).

3.5 (II) Phosphorus :

For phosphorus determination 5 g samples taken in separate digestion

tubes, were digested in the presence of 10 ml tri-acid mixture (HNO_3, $HClO_4$ and H_2SO_4 in the proportion of (10 : 4 : 1) Digest of each tube was made upto 100 ml with distilled water in volumetric flasks.

Phosphorus was determined by Barton's nitric acid ammonium molybdate reagent method as described by Kanwar and Chopra (1976) Ten ml digested solution was taken into 50 ml volumetric flask to which 10 ml ammonium molybdate reagent was added and the volume was made upto 50 ml with distilled water. The intensity of the colour development was measured with spectrophotometers at 470 nm. A blank sample was also simultaneously prepared for recording the reading.

3.6. Seed and Straw Analysis

(I) Crudeprotein/Nitrogen :

Digestion of powdered/ground seed and straw samples (1 g each) and estimation of nitrogen in the digest material were the same as in case of plant/nodule nitrogen determination.

Nitrogen percent in seeds were multiplied by a factor of 6.25 to get the crude protein percent.

(II) Phosphorus :

Theammonium molybdate reagent method as described by Kanwar and Chopra (1976) was employed for the determination of phosphorus.

3.7. Uptake of nutrient by grain, straw and the whole crop

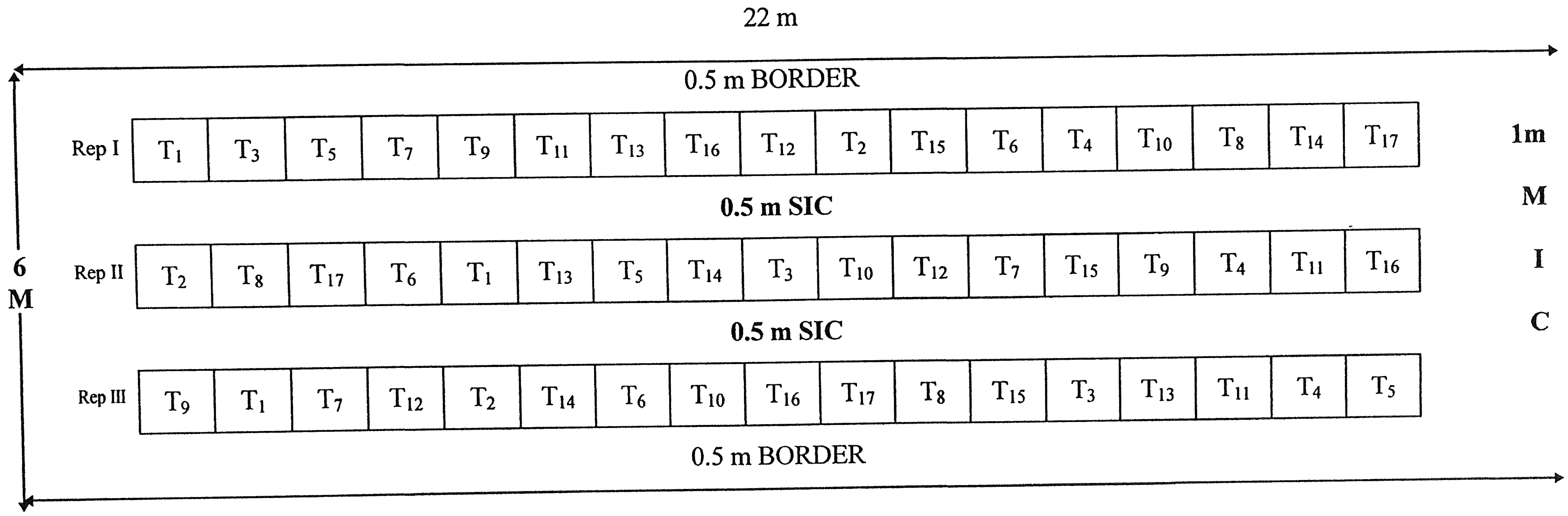
Plot-wise uptake of N and P by grain or straw was calculated by multyplying the plot-wise percent value of individual nutrient with the respective grain and straw yield of the same plot. Per plot uptake of individual nutrients by grain and straw were added together to estimate the plot-wise total uptake of nutrients by the crop. Uptake of nutrients has been expressed on the basis of mg/100g.

3.8. Statistical Analysis :

In order to draw reliable conclusions, the experimental data in relation of soil, plant, nodule and seed characteristics were analysed statistically by adopting the procedures described by Cox and Cochron (1957). Data pertaining to the observed parameters of the first, second and third experiments for the purpose of satistical analysis. Significance of treatment effect was Judged against 'F' value at 5% level of significance. C.D. at 5% was calculated to the test of significance of treatment effect.

Physico-chemical properties of soil used under field experiment

Sl. No.	Soil Properties	Year		
		1996	1997	1998
1.	pH	7.8	7.8	7.6
2.	EC	0.50	0.52	0.54
3.	CEC	25.9	26.0	24.8
4.	Organic Carbon %	0.55	0.58	0.65
5.	Total Nitrogen %	0.042	0.044	0.046
6.	Available N (Kg/ha)	98.0	105.3	110.5
7.	Available P (Kg/ha)	35.5	32.5	36.6
8.	Available K (Kg/ha)	200.6	210.8	214.0



LAY-OUT PLAN

MIC = Main irrigation channel

SIC = Sub irrigation channel

EXPERIMENT FIRST

Treatment Combination On Lentil Crop

Sl. No.	Treatment	Abbreviation
1.	Control	T_1
2.	F.Y.M.	T_2
3.	Sludge	T_3
4.	M.R.P.	T_4
5.	F.Y.M. + M.R.P.	T_5
6.	Sludge + F.Y.M.	T_6
7.	Sludge + M.R.P.	T_7
8.	Sludge + F.Y.M. + R.P.	T_8
9.	$\frac{1}{2}$ Sludge + $\frac{1}{2}$ F.Y.M. + $\frac{1}{2}$ M.R.P.	T_9
10.	F.Y.M. + R. leguminosarum	T_{10}
11.	Sludge + R. leguminosarum	T_{11}
12.	M.R.P. + R. leguminosarum	T_{12}
13.	F.Y.M. + M.R.P. + R. leguminosarum	T_{13}
14.	Sludge + F.Y.M. + R. leguminosarum	T_{14}
15.	Sludge + M.R.P. + R. leguminosarum	T_{15}
16.	Sludge + F.Y.M. + M.R.P. + R. leguminosarum	T_{16}
17.	$\frac{1}{2}$ Sludge + $\frac{1}{2}$ F.Y.M. + $\frac{1}{2}$ M.R.P. + R. leguminosarum	T_{17}

EXPERIMENT SECOND

Treatment Combination On Wheat Crop

Sl. No.	Treatment	Abbreviation
1.	Control	T_1
2.	F.Y.M.	T_2
3.	Sludge	T_3
4.	N.P.K.	T_4
5.	F.Y.M. + Sludge	T_5
6.	F.Y.M. + Azotobacterin	T_6
7.	Sludge + Azotobacterin	T_7
8.	F.Y.M. + Sludge + Azotobacterin	T_8
9.	$\frac{1}{2}$ N.P.K. + Azotobacterin	T_9
10.	F.Y.M. + Phosphobacterin	T_{10}
11.	Sludge + Phosphobacterin	T_{11}
12.	F.Y.M. + Sludge + Phosphobacterin	T_{12}
13.	$\frac{1}{2}$ N.P.K. + Phopshobacterin	T_{13}
14.	F.Y.M. + Azotobacterin + Phosphobacterin	T_{14}
15.	Sludge + Azotobacterin + Phosphobacterin	T_{15}
16.	F.Y.M. + Sludge + Azotobacterin + Phosphobacterin	T_{16}
17.	$\frac{1}{2}$ N.P.K. + Azotobacterin + Phosphobacterin	T_{17}

EXPERIMENT THIRD

Residual Effect On Gram Crop

Sl. No.	Treatment	Abbreviation
1.	Control	T_1
2.	F.Y.M.	T_2
3.	Sludge	T_3
4.	N.P.K.	T_4
5.	F.Y.M. + Sludge	T_5
6.	F.Y.M. + Azotobacterin	T_6
7.	Sludge + Azotobacterin	T_7
8.	F.Y.M. + Sludge + Azotobacterin	T_8
9.	$\frac{1}{2}$ N.P.K. + Azotobacterin	T_9
10.	F.Y.M. + Phosphobacterin	T_{10}
11.	Sludge + Phosphobacterin	T_{11}
12.	F.Y.M. + Sludge + Phosphobacterin	T_{12}
13.	$\frac{1}{2}$ N.P.K. + Phosphobacterin	T_{13}
14.	F.Y.M. + Azotobacterin + Phosphobacterin	T_{14}
15.	Sludge + Azotobacterin + Phosphobacterin	T_{15}
16.	F.Y.M. + Sludge + Azotobacterin + Phosphobacterin	T_{16}
17.	$\frac{1}{2}$ N.P.K. + Azotobacterin + Phosphobacterin	T_{17}

RESULTS AND DISCUSSION

RESULT AND DISCUSSION

Experiment -1

A field experiment was laid out with ***Lentil (Lens esculenta) variety — Type - 8*** during rabi season 1996-97 F.Y.M. and sludge were applied in soil at the rate of 12.5 t/ha and phosphate was applied as M.R.P. at the rate of 50 kg/ha P_2O_5 as basal application. ***R. leguminosarum*** was inoculated in the lentil seeds according to the requirement of the treatments as mentioned in the experimental layout. A set of experiment was laid out to incorporate half of the dose of F.Y.M. sludge and M.R.P. with or without *Rhizobia inoculation.*

From Table - 1, it was noticed that the plant heights increased at all the three successive stages of growth viz. 30, 60 and 90 days of growth with inoculation of *Rhizobium*. Further increase in lentil crop was noticed in the treatment containing M.R.P. and organic matter. F.Y.M. appears to be more effective than the sludge treatment. The vegetative growth of the legume crop is improved by the application of phosphatic fertilizer was reported as early as 1956 by Thornton. The supply of phosphorus particularly at every stage of crop growth is essential for most of the legumes (Williams, 1936) and in the absence of phosphorus growth of the legumes remains retarded (Krauss, 1932; Stitt, 1944) with stunted root system (Olson and Freid, 1957). A comparative study of growth of the crop at the three successive stages has been shown in Fig. 1. Which illustrates the influences of different treatments with or without *Rhizobia* inoculation.

The maximum crop height after 30 days was noticed with a treatment containing sludge, F.Y.M. alongwith M.R.P. having *Rhizobia* inoculation followed by half of the dose of F.Y.M., sludge and M.R.P. applications revealed in Table 1. While the maximum crop height was recorded after 60

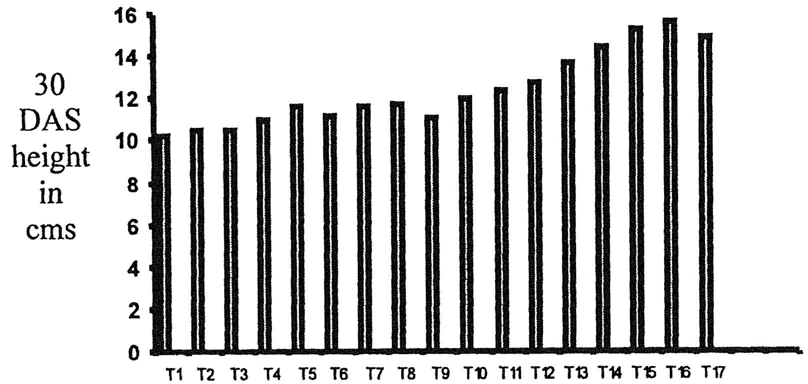
and 90 dyas 1 in treatment containing half of the doses of F.Y.M. sludge & M.R.P. with *Rhizobia*.

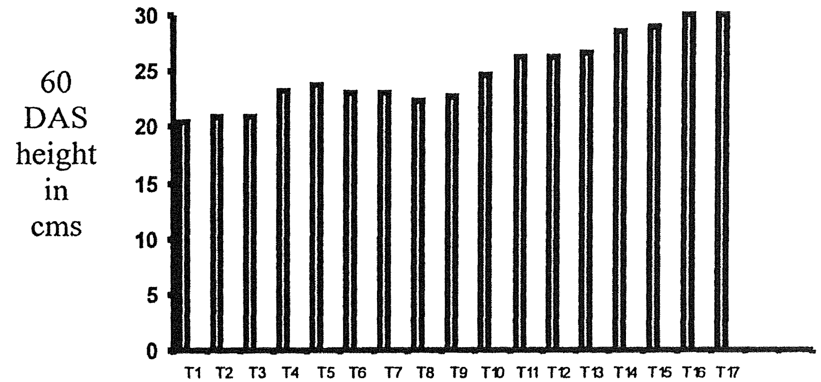
Table - 1

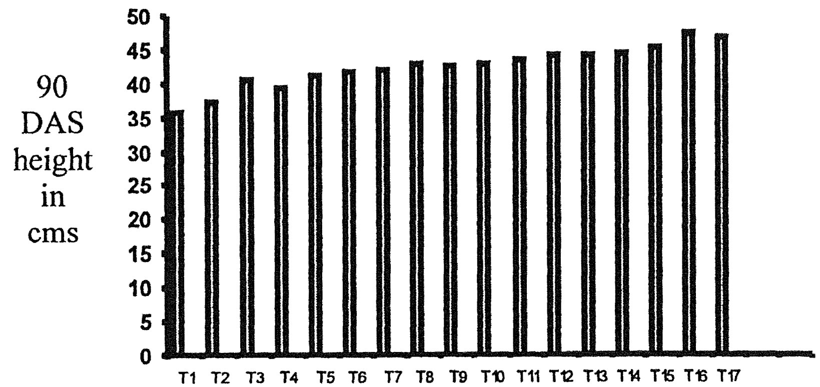
Effect of Rhizobium treated with F.Y.M. + M.R.P. + Sludge on Lentil crop height

Treatment	30 DAS height in cms	60 DAS height in cms	90 DAS height in cms
T_1	10.2	20.4	35.8
T_2	10.5	21.0	37.4
T_3	10.5	21.0	40.5
T_4	11.0	23.2	39.3
T_5	11.6	23.7	41.0
T_6	11.2	23.00	41.8
T_7	11.6	23.00	42.00
T_8	11.7	22.33	42.80
T_9	11.1	22.66	42.50
T_{10}	12	24.66	43.00
T_{11}	12.4	26.33	43.50
T_{12}	12.8	26.33	44.13
T_{13}	13.7	26.66	44.03
T_{14}	14.5	28.66	44.46
T_{15}	15.3	29.00	45.13
T_{16}	15.7	30.00	47.36
T_{17}	15.0	30.0	46.60
CD at 5%	**0.908**	**1.451**	**2.092**

Effect of Rhizobium treatd with F.Y.M. + M.R.P. + Sludge on Lentil crop height
(Table - 1)







The size and number of nodules in roots of the lentil crop may have some correlation with nitrogen fixing mechanism. Keeping this in view the number of nodules developed on the roots of the experimental crop after 50 days of growth was taken into account and some plants were taken out at random and the number of the nodules were counted and recorded in Table - 2. It was observed that application of F.Y.M. when applied alone gives a significant increase over the control but after inoculation with *Rhizobia leguminosarum* the increase of nodule number was found to be more than double. It was further noticed that the number of nodules got increased when F.Y.M. *Rhizobia* inoculated plot was supplimented with M.R.P. application. Addition of F.Y.M. + Sludge also influenced the increase in nodule formation but when M.R.P. was incorporated the number of nodules further got increased, which is revealed by perusal of the data presented in Table - 4.

Kalyan *et al* (1986) have reported increased number of nodulation and plant N content and increased seed yield by 59.2 percent and 29.3 percent respectively in lentils.

Kumar *et al* (1988) also carried out a field trial on lentil crop in calcarious soil and reported increase number of nodules and dry weight of plant. The increased seed and straw yields by 26 and 53 percent above the uninoculated control set.

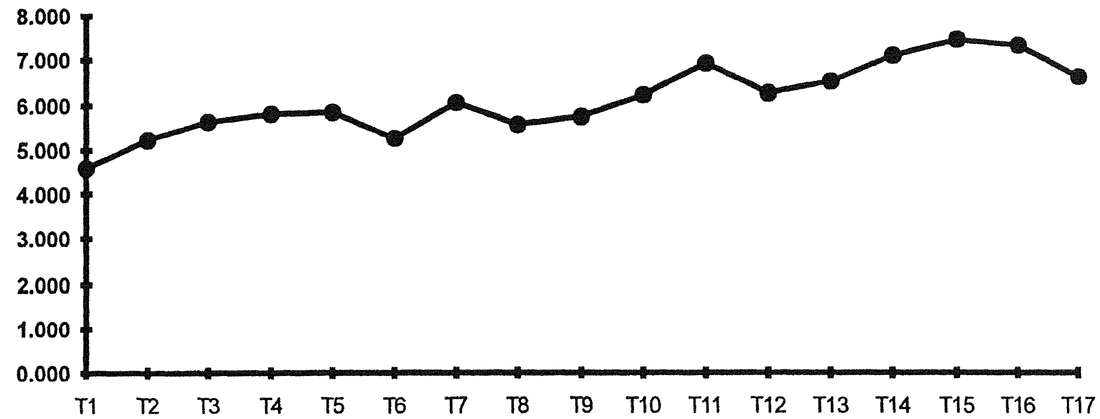
Sanoria and Malik (1981) noticed higher lentil seed and straw yield by inoculating by different strains to the extent of 1.9 t/ha and 3.06 t/ha respectively. Crude protein content also increased in *Rhizobia* inoculated plots.

Table - 2

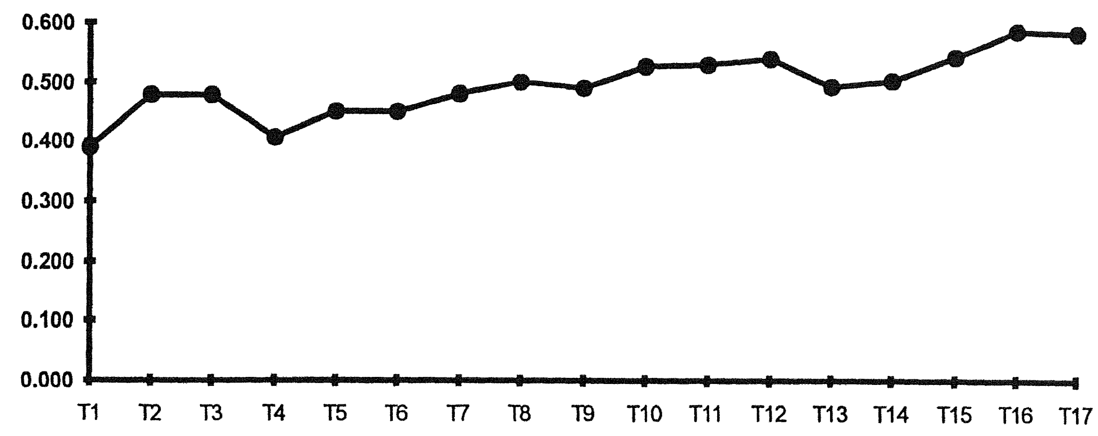
Effect of Rhizobium treated with F.Y.M. + M.R.P. + Sludge on Lentil Nitrogen and Phosphate uptake

Treatment	Number of Nodules	N- uptake by Nodules g/100g	P- uptake by Nodules mg/100g
T_1	3.000	4.567	0.390
T_2	7.000	5.197	0.480
T_3	4.330	5.600	0.480
T_4	4.000	5.780	0.407
T_5	7.330	5.853	0.453
T_6	7.660	5.277	0.453
T_7	8.660	6.077	0.483
T_8	9.660	5.557	0.503
T_9	10.000	5.753	0.493
T_{10}	11.330	6.257	0.530
T_{11}	11.330	6.957	0.533
T_{12}	12.330	6.277	0.543
T_{13}	13.330	6.563	0.497
T_{14}	14.330	7.130	0.507
T_{15}	13.660	7.520	0.547
T_{16}	15.000	7.383	0.590
T_{17}	13.330	6.660	0.587
CD at 5%	**2.016**	**0.767**	**0.094**

Effect of Rhizobium treated with F.Y.M. + M.R.P. + Sludge on Lentil Nitrogen uptake g/100g (Table - 2)



Effect of Rhizobium treated with F.Y.M. + M.R.P. + Sludge on Lentil Phosphate uptake mg/100g (Table - 2)



The analysis of nodules produced on lentil roots for their N.P. contents and recorded in the Table 3. The nitrogen content of root nodules of lentil crop increased significantly when F.Y.M. was applied. The probable explanation for the increase of nitrogen in nodules may be due to more *rhizobial* activity in fixing the atmospheric nitrogen. Sufficient amount of nutrients required for the crop growth and nodule development may be made available with the application of F.Y.M. plots receiving organic matter and phosphate have further increased in the number of nodule formation as well as their nitrogen content. Pereira and Bliss (1987) have reported that the nodule number and nodule mass have positive effect where ever application was carried out.

The phosphate content in the root nodules was determined and recorded in Table - 2, it was noticed that P content was significantly influenced with application of F.Y.M. and sludge separately and also in combination when inoculated with *Rhizobium leguminosarum*. The maximum P content in the root nodules was obtained in plots receiveing F.Y.M., sludge and M.R.P. alongwith *Rhizobia*. It appears from the data that increase amount of phosphate availability with the application of organic matter and phosphate has resulted increased P content in the root nodules. The increased amount of nitrogen and phosphate content in root nodules of the lentil crop may influence better crop growth and there by increase the productivity of the experimental crop.

Lentil crop was harvested and the straw and grain were separated which are recorded in Table 3. The grain yield found in control plot was 96 q/ha and the plot containing F.Y.M. gave 120 q. The *Rhizobia inoculation* in F.Y.M. treated plot yielded 18.6 q/ha of grains.

The F.Y.M. and phosphated sludge application alongwtih rhizobial inoculation gave the maximum grain yield of about 20.0 q/ha that is double

of the grain yield may be due to higher nutrient uptake by the crop. Organic matter addition in form of F.Y.M. and sludge contributed increased amount of available nutrient and the application of M.R.P. might have influenced the crop growth and inoculation of *Rhizobium leguminosarum* also help the crop growth through biological N_2-fixation. Organic matter itself during process of decomposition added optimum amount of nutrient as well its indirect effect on the improvement.

Table - 3

Effect of Rhizobium treatment with F.Y.M. + M.R.P. + Sludge on Lentil yield of grain and straw q/ha

Treatment	Grain	Straw	Ratio Straw/grain
T_1	9.6	19.5	2.03
T_2	12.0	23.2	1.9
T_3	11.2	21.0	1.8
T_4	12.5	22.8	1.8
T_5	13.7	21.8	1.5
T_6	15.0	22.2	1.4
T_7	14.8	22.8	1.5
T_8	16.2	24.8	1.5
T_9	16.1	24.0	1.4
T_{10}	16.9	26.3	1.5
T_{11}	16.9	26.5	1.5
T_{12}	17.7	26.7	1.5
T_{13}	18.2	27.5	1.5
T_{14}	18.0	28.2	1.5

T_{15}	19.7	28.0	1.4
T_{16}	20.0	29.1	1.4
T_{17}	19.2	28.5	1.4
CD at 5%	**7.125**	**20.682**	

A persual of result (Table - 3) showed that the lentil grain yield in q/ha with different treatments with or without *Rhizobia inoculation* F.Y.M. sludge and M.R.P. separately and their combined application with or with out *Rhizobia inoculation* gave a significant higher yield over the control set.

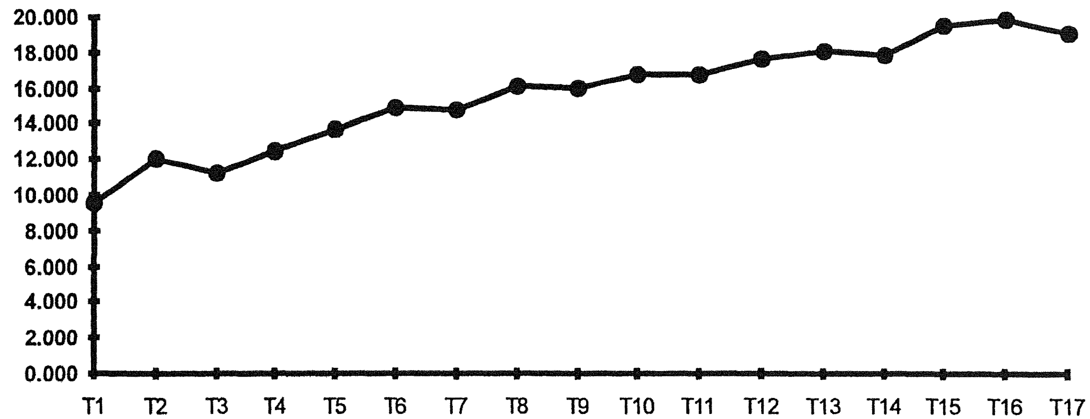
The increase in yield of lentil crop due to application of organic matter and phosphate may be due to supply of sufficient amount of nutrient through the decomposition of the organic matter and release of available phosphate for the crop. The maximum grain yield was recorded in the treatment containing F.Y.M. + Sludge + M.R.P. alongwith *Rhizobia* inoculation. The response was over one hundred percent from the control set.

Results reported by Prasad et al (1991) also confirmed this finding that addition of phosphatic fertilizer alongwith organic matter obtained significant increase in growth, grain yield, dry matter and nutrient uptake in mustard crop in alluvial soil.

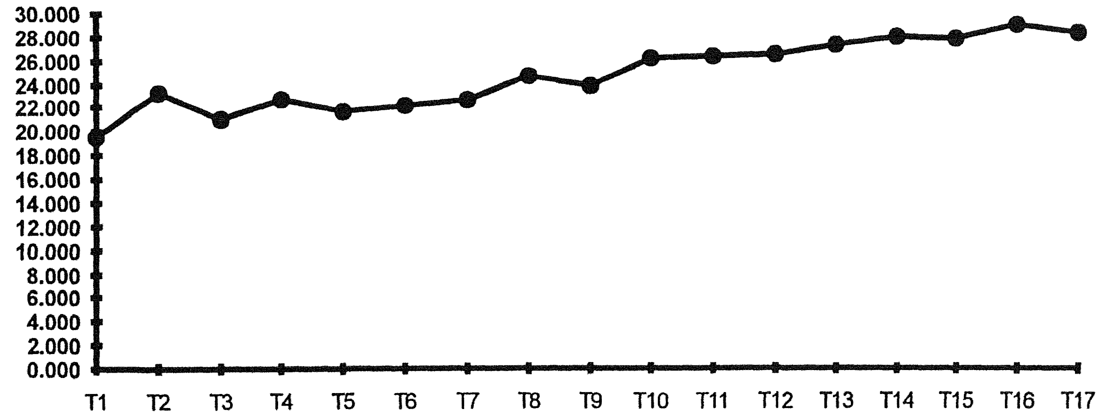
The physical properties of soil has resulted favourable condition for the crop growth. The effect of *Rhizobium* on development of good size of nodules on the root system of lentil crop might have benefited by application of M.R.P.

A similar trend in straw production was noticed and straw yield data are recorded Table - 3. The grain straw ratio for lentil crop comes to nearly 1 : 2. The *rhizobial inoculated* seeds of lentil crop has found to influence the total yield of the crop in presence of organic matter and phosphate.

Effect of Rhizobium tratment with F.Y.M. + M.R.P. + Sludge on Lentil yield of Grain q/ha (Table - 3)



Effect of Rhizobium tratment with F.Y.M. + M.R.P. + Sludge on Lentil yield of Straw q/ha (Table - 3)



For evaluating the quality of the lentil crop the crude protein and phosphate content were determined in grain as well as straw and recorded in Table - 4, for crude protein calculation the nitrogen content is multiplied with a factor 6.25 for giving an approximate value. The N/P ratio was also worked out by dividing nitrogen content by amount of P-uptake by the plant and N/P ratio emphasizes the quality of the crop. The crude protein content of the lentil grain was found to have 22.4 percent in the control plant and plot containing F.Y.M. with *Rhizobia inoculation* contained 24.4 percent i.e. an increase of about 2.00 percent was estimated due to F.Y.M. and rhizobial inoculation. The maximum crude protein in the grain was obtained in the treatment containing half of the total amount of sludge + F.Y.M. + M.R.P. with *Rhizobial inoculation.*

Sharma *et al* (1982) have analyse the total N uptake by *Rhizobia inoculated* lentil crop and obtained positive correlation with nodule dry weight, straw and seed yields.

Table - 4

Effect of Rhizobium treated with F.Y.M. + M.R.P. + sludge on Lentil grain Crude Protein and Phosphate uptake

Treatment	Crude Protein g/100g	Phosphate mg/100g
T_1	22.433	412.000
T_2	23.900	414.000
T_3	23.900	414.000
T_4	24.000	470.000
T_5	24.100	419.000
T_6	24.000	417.000
T_7	24.000	420.000

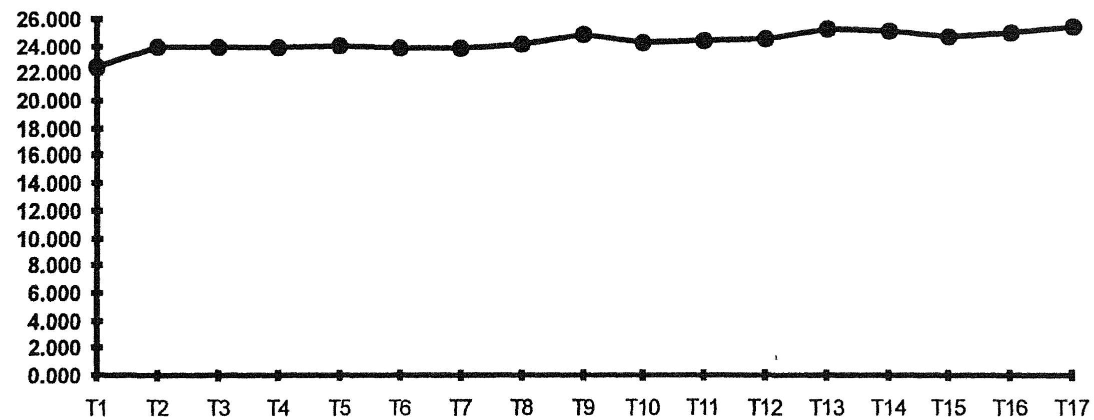
T_8	24.300	421.333
T_9	25.000	417.000
T_{10}	24.400	420.000
T_{11}	24.600	422.000
T_{12}	24.667	426.000
T_{13}	25.400	429.000
T_{14}	25.300	423.333
T_{15}	24.800	430.667
T_{16}	25.133	441.667
T_{17}	25.500	438.333
CD at 5%	**N. S.**	**7.942**

The effect of phosphate on crude protein content in the lentil grains was found to increase to about 2 percent over the control set. The cumulative effect of organic matter and phosphate in rhizobia inoculated plots furnished increased amount of available nutrients viz. Nitrogen fixed through legumes, phosphate through application of M.R.P. and other macro and micro nutrients available from F.Y.M. decomposition.

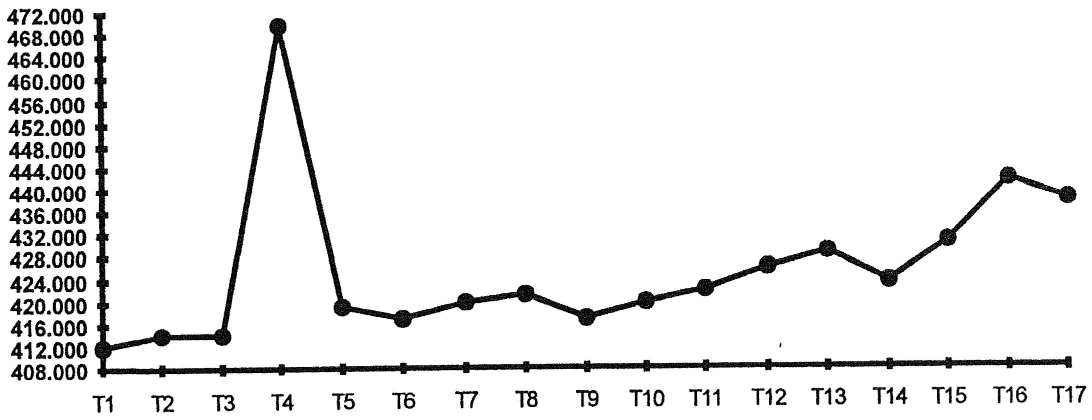
The phosphate content of the lentil grain was found to have 0.4 percent in the control plot and when F.Y.M. was applied alongwith *Rhizobia* inoculation P content increased by 8.0 mg/100 g but the phosphated plot having organic matter and *Rhizobial inoculation* there was marked increase to the extent of 0.429 mg/100g. The maximum P content was obtained in grains where combined effect of F.Y.M. and sludge alongwith M.R.P. and *rhizobia inoculation* was experimented.

Tilak and Singh (1996) have reported that lentil can fix 35 to 100 kg N/ha and if the addition of organic matter and phosphate were applied in the

Effect of Rhizobium tratment with F.Y.M. + M.R.P. + Sludge on Lentil grain Crude Protein uptake g/100g (Table - 4)



Effect of Rhizobium tratment with F.Y.M. + M.R.P. + Sludge on Lentil grain Phosphate uptake mg/100g (Table - 4)



field the upper limit of 100 kg N/ha may be considered. The supply of sufficient amount of Nitrogen and Phosphate in this field trial Salem and Massari (1986) carried out two field experiments at Alexandria with Rhizobia inoculated faba beans in phosphate applied plots and obtained increased seed yield/plant, number of pods/plant and 100-seed wt in both seasons, but number of branches/plant, plant height and seed protein content only in 1980-81, shoot and nodule DW/plant did not respond to P application.

Azad *et al* (1991) in a field trial in Gurudaspur at Punjab have noticed increased Lentil grain yield in all *Rhizobia inoculated* plots at different levels of P application.

Table - 5

Effect of Rhizobium treated with F.Y.M. + M.R.P. + Sludge on Lentil straw Nitrogen and Phosphorus uptake

Treatment	Nitrogen g/100g	Phosphorus mg/100g	Ratio N/P
T_1	6.300	0.490	12.85
T_2	6.767	0.510	13.25
T_3	6.667	0.500	13.32
T_4	7.300	0.507	12.6
T_5	7.000	0.530	13.20
T_6	7.100	0.510	13.92
T_7	7.567	0.520	14.53
T_8	7.300	0.560	13.03
T_9	8.200	0.480	17.08
T_{10}	8.300	0.490	16.93
T_{11}	8.800	0.500	17.6

T_{12}	8.900	0.530	16.79
T_{13}	9.100	0.580	15.68
T_{14}	9.100	0.550	16.54
T_{15}	9.367	0.577	16.42
T_{16}	9.800	0.610	16.06
T_{17}	9.167	0.530	17.28
CD at 5%	**.952**	**N.S.**	

The composition of the lentil straw particularly their N and P content and the N/P ratio have been recorded in Table 5. The N content of straw was found to have 6.3 mg/100 g and with the addition of the F.Y.M. in *Rhizobia inoculated* plot yielded 8.3 mg N/100 g of straw and P content was estimated 0.49%. The maximum N content was reported in plots containing F.Y.M. + Sludge alongwith M.R.P. incorporated *Rhizobia inoculation* to the extent of 9.8 mg N/100 g and 0.6/percent P in the lentil straw. Lentil straw is mostly used for cattle feeding and the quality of the straw thus got improved by increasing their N and P contents. The higher yield as well as improved quality of straw as fodder can bring this type of integrated management of the lentil crop which gave higher grain yield of better qauality and may be used as pulse in our Indian diets having increased protein content.

Table - 6

Physico-chemical properties of soil used under field experiment after harvesting Lentil crop 1997

Treatment	Organic Carbon %	Total N %	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	0.53	0.040	106.2	20.2	185.0

T_2	0.60	0.049	120.0	28.0	192.0
T_3	0.58	0.043	118.2	30.0	194.2
T_4	0.50	0.046	108.0	35.0	190.0
T_5	0.60	0.049	118.8	38.0	191.0
T_6	0.66	0.048	122.2	30.1	196.4
T_7	0.59	0.050	119.4	40.4	195.4
T_8	0.67	0.050	120.2	41.1	194.4
T_9	0.62	0.044	120.1	32.0	192.4
T_{10}	0.61	0.050	133.2	30.0	192.8
T_{11}	0.58	0.054	136.0	32.0	195.0
T_{12}	0.62	0.067	134.0	36.0	198.0
T_{13}	0.64	0.063	136.0	38.0	200.0
T_{14}	0.68	0.069	140.0	32.0	201.0
T_{15}	0.60	0.062	142.0	38.0	200.2
T_{16}	0.72	0.066	148.0	42.1	205.4
T_{17}	0.66	0.054	144.0	36.0	195.0

EXPERIMENT 2

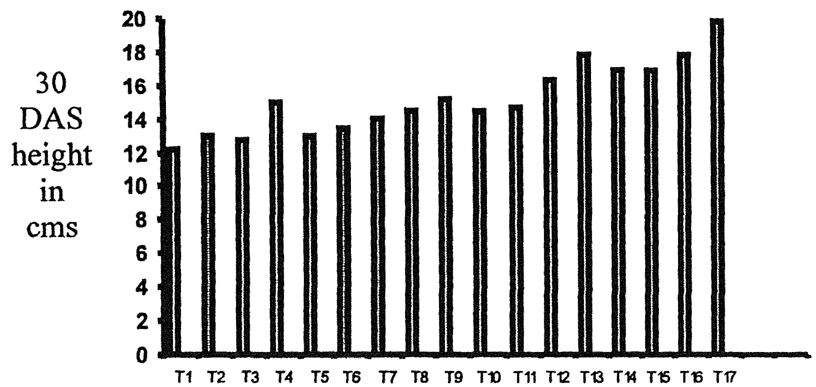
A field trial was conducted with 17 treatments in RBD to find out response of *Azotobacter* and *phosphobacterin* inoculated wheat ***(Triticum aestivum)*** seeds at SDI experimental form during 1997-98 in with F.Y.M., Sludge and N.P.K. combinations. The plant growth of the wheat crop was study at 30, 60 and 90 days stages which is recorded table 7. The plant height after 30 days of growth in control set was found to measure 12.2 cms and when F.Y.M. was applied crop height increase to 13.0 cms. Inoculated seeds of with *Azotobacterin* in F.Y.M. treated plot the crop height got increased upto 13.5 cms i.e. about 11 percent height of the crop was affected by F.Y.M. and *Azotobacterin* inoculation. N.P.K. in 120 : 60 : 60 ratio was applied are 2:1:1 and the height of plant was recorded having 15 cms but when half of the N.P.K. doses that is 60 : 30 : 30 was applied and inoculation of *Azotobacterin* was carried out the crop height was recorded 15.2 cms. In similar sets of treatment were laid out by inoculating *phosphobacterin* in place of *Azotobacterin* but in some cases the combined effect of *Azotobacterin* and *phosphobacterin* were also studied. The inoculated *phosphobacterin* in F.Y.M. treated plot recorded crop height to the extent of 14.6 cms. In set containing F.Y.M. + Sludge alongwith *phosphobacterin*, height of the wheat plant was recorded 16.5 cms while with the same combination of F.Y.M. and Sludge *Azotobacterin* inoculation recorded 14.5 cms. Thus it reveals that respons of *phosphobacterin* on crop height after 30 days proves better as compared to *Azotobacterin.* The maximum crop height 20.0 cms was observed in treatment containing 1/2 NPK dose i.e. 60 : 30 : 30 with inoculation *Azotobacterin* as well as *phosphobacterin.*

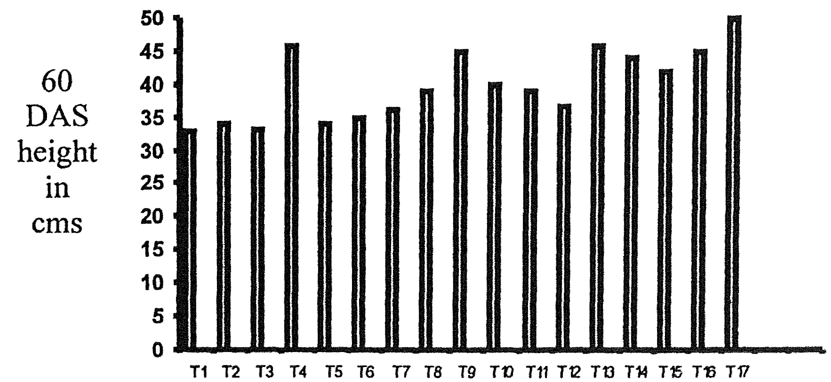
Table - 7

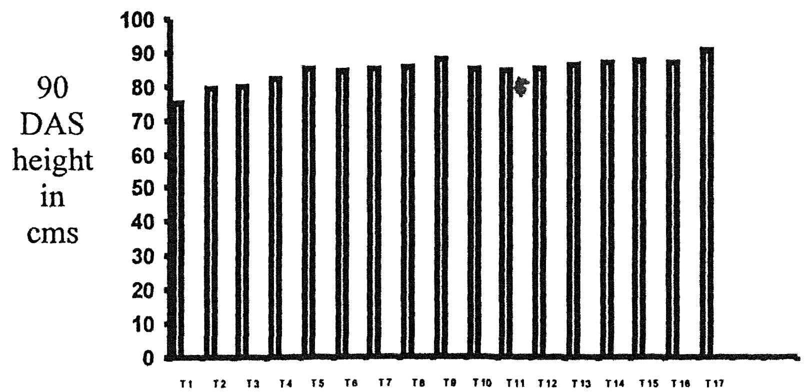
Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on wheat crop

Treatment	30 DAS height in cms	60 DAS height in cms	90 DAS height in cms
T_1	12.2	32.8	75.0
T_2	13.0	34.0	79.0
T_3	12.8	33.0	80.0
T_4	15.0	46.0	82.2
T_5	13.0	34.0	85.4
T_6	13.5	35.0	84.8
T_7	14.1	36.0	85.4
T_8	14.5	39.0	85.6
T_9	15.3	45.0	88.0
T_{10}	14.6	40.0	85.2
T_{11}	14.8	39.0	84.8
T_{12}	16.5	36.6	85.2
T_{13}	18.0	46.0	86.6
T_{14}	17.0	44.0	87.2
T_{15}	17.0	42.0	87.5
T_{16}	18.0	45.0	87.2
T_{17}	20.0	50.0	90.5
CD at 5%	**N.S.**	**2.331**	**N.S.**

Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on wheat crop (Table - 7)







The growth of wheat crop was studied after 60 days stage which is recorded in table 7. The plant height after 60 days of growth in control set was found to measure 32.8 cms and when F.Y.M. was applied the crop height increased to 34 cms. Inoculated seeds of with *Azotobacterin* in F.Y.M. treated plot the crop height got increased up to 35 cms i.e. about 7 percent height of the crop which was affected by F.Y.M. and *Azotobacterin* N.P.K. in 120 : 60 : 60 ratio when applied the height of wheat crop was recorded to the extent of 46.0 cms but when half of the N.P.K. dose i.e. (60 : 30 : 30) was applied with inoculation of *Azotobacterin*, the crop height was recorded 45.0 cms. In similar way a set of treatment was laid out by inoculating *phosphobacterin* in place of *Azotobacterin* and in some cases the combined effect of *Azotobacterin* and *phosphobacterin* were also studied. The inoculated *phosphobacterin* in F.Y.M. treated plots, recorded height of the crop to 40 cms. In a set containing F.Y.M. and sludge alongwith *phosphobacterin* the height of the wheat plant was recorded 36.6 cms while similar combination of F.Y.M. and sludge with *Azotobacterin* inoculation recorded 39.0 cms. Thus it reveals that respons of *phosphobacterin* on crop height after 60 days proved better as compared to *Azotobacterin*. The maximum crop height of 50.0 cms was observed in the treatment containing 1/2 N.P.K. doses i.e. 60 : 30 : 30 with inoculation of *Azotobacterin* as well as *phosphobacterin*.

The height of the wheat crop was studied at 90 days of growth which is recorded table 7. The plant height after 90 days of growth in control set was found to measure 75.0 cms and when F.Y.M. was applied the crop height increased to 79.6 cms. Inoculated wheat seeds with *Azotobacterin* in F.Y.M. treated plots, the crop height got increased upto 85.4 cms i.e. about 13 percent height of the crop was affected by F.Y.M. and *Azotobacterin* inoculation. The N.P.K. in 120 : 60 : 60 ratio was applied and the height of plant was recorded having 82.2 cms but when half of the N.P.K. dose i.e. 60 :

30 : 30 was applied and inoculation of *Azotobacterin* was carried out, the crop height was recorded 88.0 cms. A similar set of treatment was laid out by inoculating phosphotactrine in place of *Azotobacterin* and in some treatments the combined effect of *Azotobacterin* and *phosphobacterin* were also studied. The inoculated *phosphobacterin* in F.Y.M. treated plot recorded crop height to the extent of 85.2 cms. In a set containing F.Y.M. + Sludge alongwith *phosphobacterin*, height of the wheat plant was recorded 85.2 cms while the combination of F.Y.M. and Sludge with *Azotobacterin* inoculation recorded 85.6 cms crop height. Thus it reveals that response of *phosphobacterin*, and *Azotobacterin* is not having significant defference. The maximum crop height 90.5 cms was observed in treatment containing 1/2 N.P.K. dose i.e. 60 : 30 30 with the inoculation of *Azotobacterin* as well as *phosphobacterin*.

Table - 8

Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith fertilizers on wheat crop yield q/ha

Treatment	Grain in q/ha	Straw in q/ha	Ratio Straw/grain
T_1	20.0	38.0	1.9
T_2	25.2	43.5	1.7
T_3	25.0	44.9	1.7
T_4	27.8	46.5	1.6
T_5	25.8	45.0	1.7
T_6	26.9	47.1	1.7
T_7	27.2	47.8	1.7
T_8	27.0	48.0	1.7

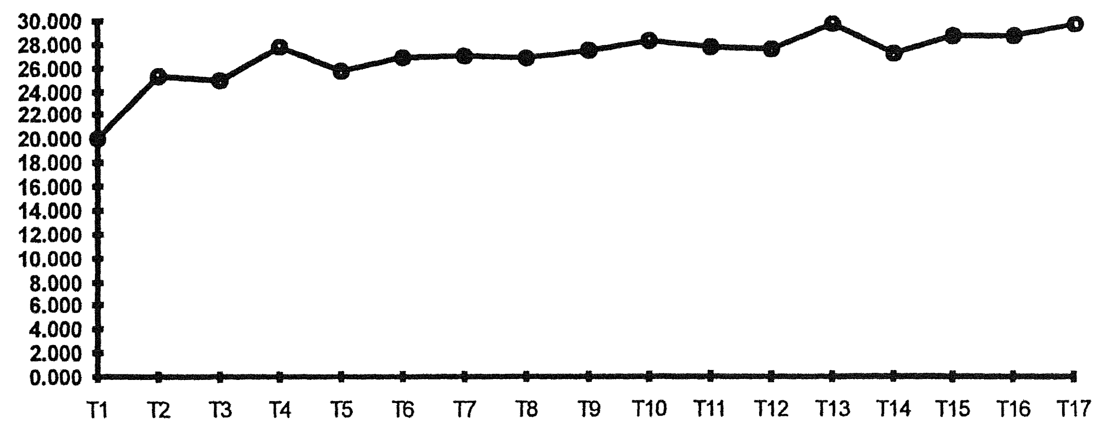
T_9	27.7	48.5	1.7
T_{10}	28.5	50.0	1.7
T_{11}	27.9	49.5	1.7
T_{12}	27.8	49.0	1.7
T_{13}	30.0	52.5	1.7
T_{14}	27.5	52.6	1.9
T_{15}	29.0	49.1	1.6
T_{16}	29.0	51.5	1.9
T_{17}	30.0	52.3	1.7
CD at 5%	**55.85** ?	**N.S.**	

The grain yield of wheat crop in q/ha was recorded in table 8. The control set yielded 20.0 q/ha i.e. 20 q/ha of wheat grain and treatment containing F.Y.M. was found to yield 25.2 q/ha N.P.K. (120 : 60 : 60) produced 27.8 q/ha which is about 36 percent higher than control. When F.Y.M. treated plot was inoculated with *Azotobacterin*, the grain yield was recorded 26.9 q/ha i.e. about 15 percent of increased yield was due to *Azotobacterin* inoculation in F.Y.M. treated plot. By inoculating *phosphobacterin in* F.Y.M. treated plot the grain yield was recorded 28.5 q/ha i.e. increase of about 23 percent was found due to *phosphobacterin* inoculation. Which shows that *phosphobacterin* may be more effective as compared to *Azotobacterin.* The probable reason may be due to increased availability of phosphates by *phosphobacterin* on F.Y.M. application.

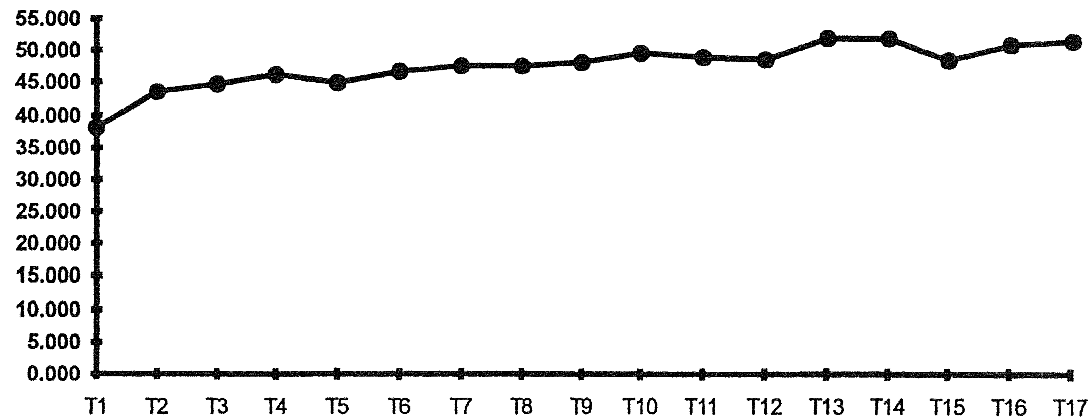
The native phosphate present in the soil may get solubilized due to production of organic acids during the decomposition of F.Y.M. Half of the N.P.K. dose (60 : 30 : 30) alongwith inoculation of *Azotobacterin* and

Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith fertilizers on Wheat Grain yield q/ha

(Table - 8)



Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith fertilizers on Wheat Straw yield q/ha (Table - 8)



phosphobacterin produced separately 27.7 q/ha and 30.0 q/ha respectively. In this case also *phosphobacterin* responded better than *Azotobacterin.* The reason of increased grain production may be due to more availability of phosphates by the activities of *phosphobacterin.*

Result reported by Prasad *et al* (1991) also confirmed this finding that addition of phosphatic fertilizer alongwith organic matter brought about significant increase in growth grain yield dry matter and nutrient uptake in mustard crop in alluvial soils.

The phosphatic source applied in this experiments was M.R.P. and Verma (1982) obtained increased availability of phosphate when M.R.P. was applied as phosphatic fertiliser. The maximum grain yield was produced in the treatment containing half N.P.K. dose (60 : 30 : 30) inoculated with *Azotobacterin* and *phosphobacterin* to the extent of 30 q/ha which is nearly 50 percent increased yield over the control set.

The straw yield was recorded in table 8 and it was noticed that a similar trend in straw production was observed as in the case of grain yield recorded in table 8.

Wheat grain were analysed for their N and P contents and tabulated 9. It was noticed that N uptake in grain was found 1.75 percent in the control set. While 1.78 percent was analysed when crop was incorporated with F.Y.M. application when N.P.K. (120 : 60 : 60) was applied there was increased N uptake to the extent of 1.93 percent. It was observed that the application of F.Y.M. increased not only crop yield but also its nutrient content specially N content which coresponds to crude protein content. Inoculation of *Azotobacterin* as well as *phosphobacterin* has effected the N uptake separately as well as in their combination. With addition of organic matter i.e. F.Y.M. and sludge also significantly affect the grain yield as well as their

N contnet. The maximum N uptake was found in treatment containing half of the N.P.K. dose where inoculation of *phosphobacterin* and *Azotobacterin* was conducted.

The increased N uptake by wheat grains may be due to more availability of nitrogen which has been added in the soil solution through nitrogenous fertilizer, F.Y.M. and sludge moreover nitrogen from the atmosphere may be fixed by *Azotobacterin* inoculation.

Table -9

Effect of Azotobacterin and phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Wheat Grain Nitrogen and Phosphate Uptake in ppm

Treatment	N	P	Ratio N/P
T_1	1.750	0.035	50.0
T_2	1.780	0.044	40.4
T_3	1.800	0.036	50.0
T_4	1.930	0.044	43.8
T_5	1.820	0.036	50.5
T_6	1.800	0.042	42.8
T_7	1.950	0.040	48.7
T_8	2.010	0.041	49.0
T_9	2.010	0.040	49.0
T_{10}	2.170	0.047	46.1
T_{11}	2.080	0.039	53.3
T_{12}	2.060	0.039	52.8

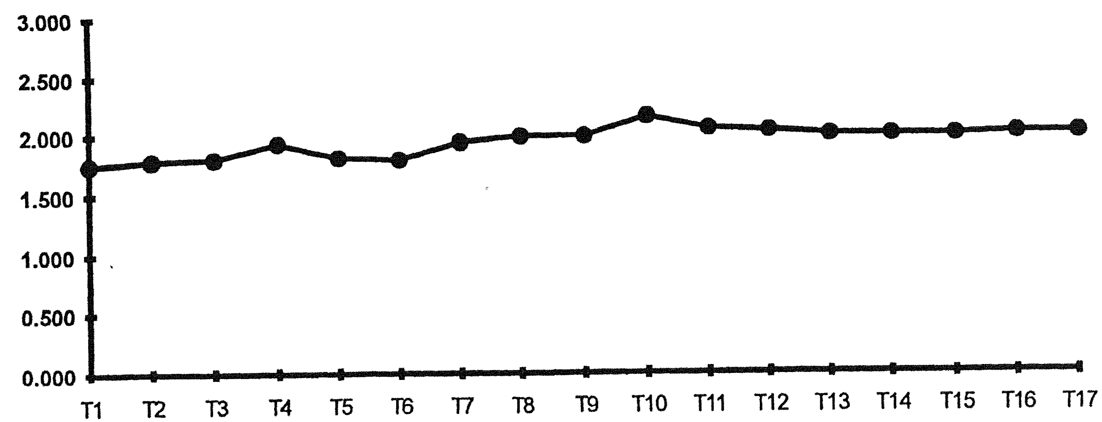
T_{13}	2.017	0.049	41.0
T_{14}	2.030	0.044	46.1
T_{15}	2.030	0.041	49.5
T_{16}	2.043	0.048	42.5
T_{17}	2.043	0.049	41.6
CD at 5%	**0.216**	**.023**	

Tippannavor *et al* (1991) have reported that addition of F.Y.M. to soil proved beneficial to *azotobacter* and found increased soil N content.

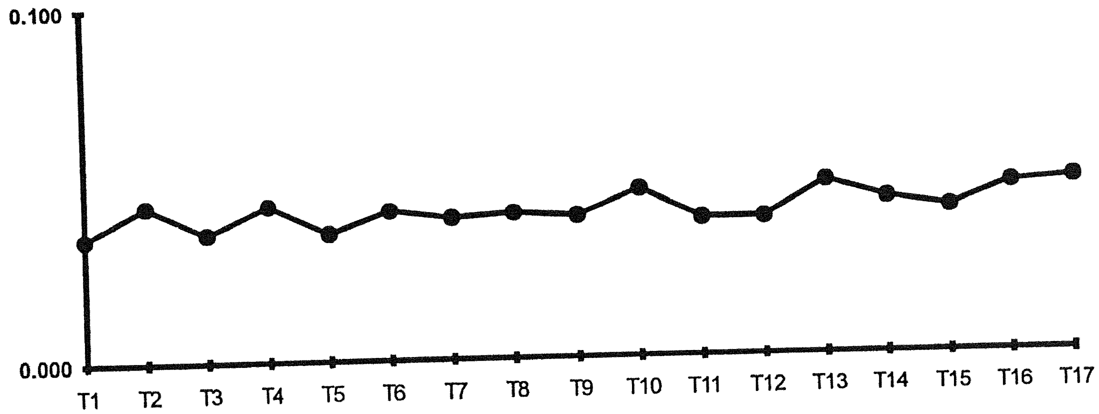
Tomar *et al* (1998) in a field trial obtained increased seed yield of ***Cicer aeritinum*** in rock phosphate applied plots inoculated with phosphate solubilizing bacteria in M.P. soils.

The grains were analysed for their P uptake and recorded in table 9. The P uptake was estimated 0.035 percent in the control set and with the F.Y.M. application the P content got slightly increased to 0.041 percent which may be due to increased amount of available P_2O_5 through F.Y.M. decomposition. Inoculation of *Phosphobacterin* in F.Y.M. treated plot has influenced the P uptake in grains due to absorption of more P_2O_5 by the crop root system. The N.P.K. applied plots where P was added in the form of M.R.P. found to affect the phosphate uptake to the extent of 0.044 percent by the wheat grain and where *Phosphobacterin* was inoculated with 1/2 N.P.K. (60 : 30 : 30) added plots, the P uptake 0.049 percent was estimated in the grains, while *Azotobacterin* and *phosphobacterin* inoculated plots with organic matter applied treatment uptake of phosphate by grains was found 0.048 percent. The influenced of *Azotobacterin* on P uptake by grains was found almost negligible. The maximum P uptake was recorded was two sets of treatment that is one with half of the doses of N.P.K. (60 : 30 : 30) inoculated with

Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Wheat Grain Nitrogen uptake in ppm (Table - 9)



Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Wheat Grain Phosphate uptake in ppm (Table - 9)



phosphobacterin and the other in similar treatment were addition of *Azotobacterine* inoculation was carried out.

Table - 10

Effect of Azotobacterin and Phosphobacterine with F.Y.M. + Sludge alongwith N.P.K. fertilizers on wheat straw Nitrogen and Phosphate uptake in PPM

Treatment	N	P	Ratio N/P
T_1	0.300	0.052	5.76
T_2	0.320	0.053	6.03
T_3	0.333	0.056	5.94
T_4	0.380	0.061	6.22
T_5	0.350	0.057	6.14
T_6	0.380	0.059	6.44
T_7	0.390	0.059	6.61
T_8	0.410	0.060	6.83
T_9	0.430	0.061	7.04
T_{10}	0.360	0.056	6.42
T_{11}	0.380	0.060	6.33
T_{12}	0.430	0.061	7.04
T_{13}	0.440	0.065	6.76
T_{14}	0.450	0.064	7.03
T_{15}	0.470	0.067	7.01
T_{16}	0.460	0.065	7.07
T_{17}	0.480	0.069	6.95
CD Value at 5%	**0.040**	**.0014**	

The N and P content in wheat straw were estimated and recorded table 10. The nitrogen uptake in control plots by wheat straw was found 0.30 percent and with F.Y.M. added plot. The N uptake by straw got increased 0.32 percent a similar trends in the increased of N and P content by wheat straw was obtained as influenced by other treatment as was observed in case of wheat grain. The explanation for increased N and P uptake by straw may be due to higher amount of absorption of N and P by the plant roots as the result out increased availability of these nutrients in the soil environment by the interaction of organic matter, N.P.K. and *Azotobacterin* + *Phosphobacterin* in different combinations.

Table -11

Physico-chemical properties of soil used under field experiment after harvesting Wheat Crop

Treatment	O C (%)	Total (%)	Available N kg/ha	Available P_2O_5 kg/ha	Available K_2O kg/ha
T_1	0.58	0.045	112.2	25.0	195.0
T_2	0.65	0.054	125.0	33.0	197.0
T_3	0.63	0.048	123.2	35.3	199.2
T_4	0.58	0.046	124.0	38.1	205.4
T_5	0.57	0.056	126	34.2	198.0
T_6	0.68	0.056	128	26.0	195.1
T_7	0.68	0.054	128.2	26.1	196.1
T_8	0.70	0.059	132.0	36.0	200.2
T_9	0.62	0.054	128.0	36.2	204.2
T_{10}	0.66	0.056	126	37.0	198.0

T_{11}	0.64	0.052	124.0	36.8	200.0
T_{12}	0.66	0.057	127	38.2	208.0
T_{13}	0.62	0.053	126.2	40.0	210.5
T_{14}	0.68	0.057	135	38.0	207.2
T_{15}	0.67	0.052	134.5	44.0	210.8
T_{16}	0.72	0.064	140.0	46.0	215.0
T_{17}	0.70	0.063	137.0	43.0	211.8

EXPERIMENT - 3

A residual crop Gram (***Cicer arietnum***) variety – type-1 was growth in plots where wheat was harvested after keeping fallow in the Kharif season. The crop heights were recorded at two stages of growth i.e. after 45 days and 90 days from the critical examination of the data presented in the table 12 it was noticed that the trend in increased crop growth was quite similar to that as was obtained in the main wheat crop.

From the data recorded in table 12 the explanation for the increased growth was found due to the presence of sufficient nutrients after the harvest of the wheat crop. The addition of F.Y.M. and sludge at the rate of 12.5 t/ha as organic materials which are considered to have residual effect for the next term. Where N.P.K. was applied in the first crop a significant increase in the crop growth at two different stages reveals optimum nutrient present in the soil and the probable reason may be due to application of M.R.P. as source of phosphate to the crop which seem to interact with nitrogenous and potash fettiliser and might have bound them as insoluble compounds which got released for the crop uptake after laps of time and result of microbial activities. Inoculation of *Azotobacterin* as well as *phosphobacterin* in the main crop might have grown to large bacterial population and their influence on mineralization have caused increase in the nutrient availability.

Table -12

Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizer on Gram Crop

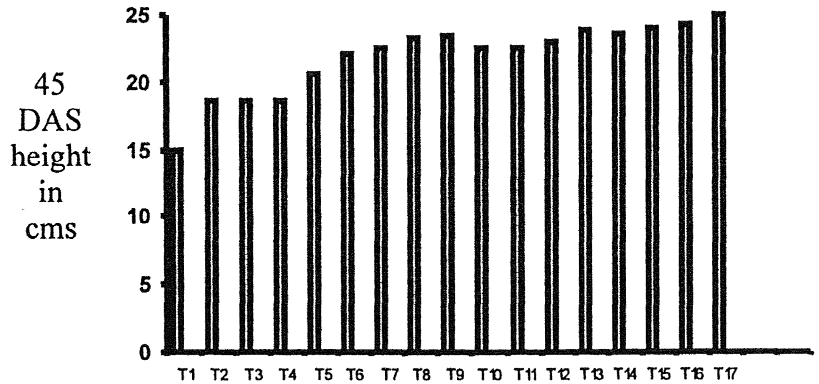
Treatment	45 DAS height in cms	90 DAS height in cms
T_1	15.0	38.0

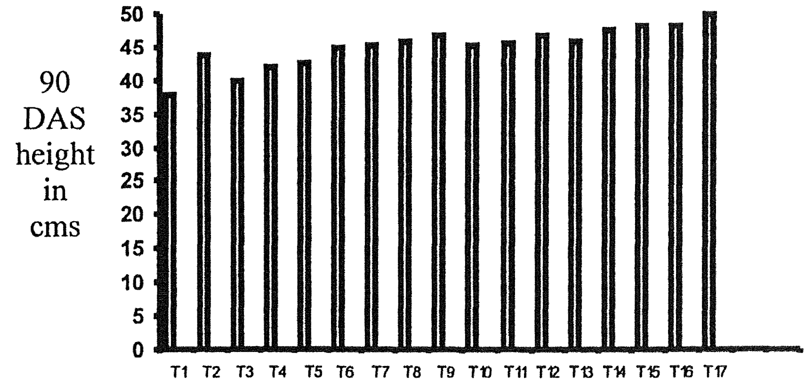
T_2	18.6	43.8
T_3	18.7	40.0
T_4	18.6	42.0
T_5	20.5	42.6
T_6	22.0	45.0
T_7	22.5	45.2
T_8	23.2	46.0
T_9	23.4	46.6
T_{10}	22.5	45.4
T_{11}	22.5	45.7
T_{12}	23.0	46.6
T_{13}	23.8	45.8
T_{14}	23.5	47.6
T_{15}	24.0	48.3
T_{16}	24.2	48.2
T_{17}	25.0	50.0
CD at 5%	**.303**	**2.495**

After harvesting the Gram crop, grains and straw were separated and recorded in table 13.

The maximum yield of grains and straw was obtained in plots containing F.Y.M. and sludge having *Azotobacterin* and *phosphobacterin* inoculation in the main wheat crop to the extent of 15 q/ha over to control which yielded 10 q/ha. It shows 50 percent increase in the Gram grains yield over the control plots. Response of organic matter in increasing the yield of

Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Gram Crop
(Table - 12)





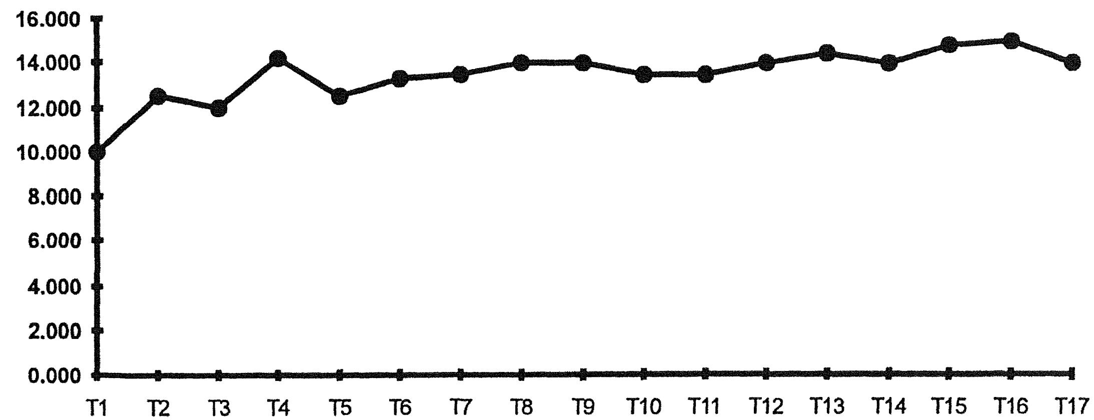
one residual crop without any application of fertilizer or manure may prove an important factor in planning an economical crop rotation.

Table - 13

Residual Effect of Azotobacterin and phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizer on Gram Crop Grain and Straw Yield

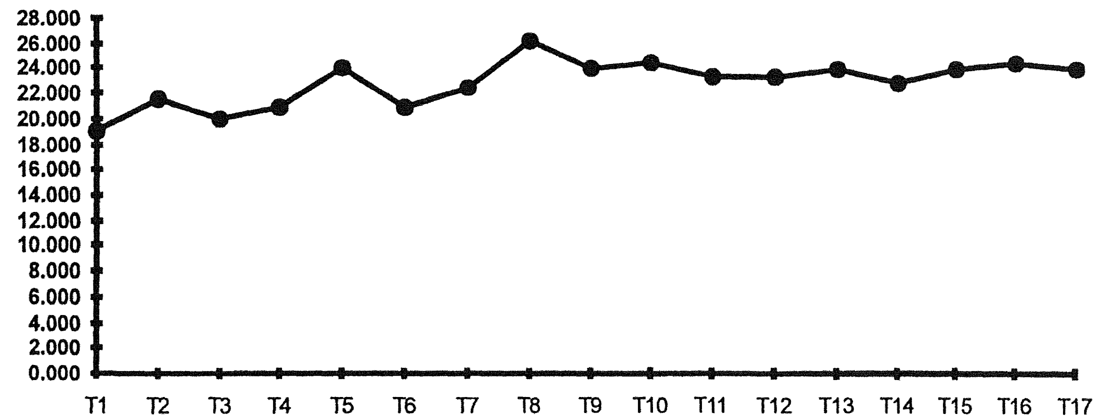
Treatment	Grain q/ha	Straw q/ha	Ratio Straw/grain
T_1	10.0	19.0	1.9
T_2	12.5	21.5	1.7
T_3	12.0	20.0	16
T_4	14.2	21.0	1.4
T_5	12.5	24.0	1.9
T_6	13.3	21.0	1.5
T_7	13.5	22.5	1.6
T_8	14.0	26.3	1.8
T_9	14.0	24.0	1.7
T_{10}	13.5	24.5	1.8
T_{11}	13.5	23.5	1.7
T_{12}	14.0	23.5	1.6
T_{13}	14.5	24.0	1.6
T_{14}	14.0	23.0	1.6
T_{15}	14.8	24.0	1.6
T_{16}	15.0	24.5	1.6
T_{17}	14.0	24.0	1.7
CD at 5%	**2.331**	**2.332**	

Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Gram Crop Grain Yield (q/ha) (Table - 13)



Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Gram Crop Straw Yield (q/ha)

(Table - 13)



Sharma *et al* (1998) in a field trial at Pantnagar grown a residual maize crop where ***Cicer arietinum*** was taken as main crop inoculated with Rhizobium in phosphated plot. A significant increase in the crop yield was obtained in the treatment containing phosphate and rhizobia inoculation over the control plots.

Table - 14

Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizer on Gram Crop Number of Nodules and Uptake of N and P

Treatment	Number of Nodules	Nitrogen uptake g/100 g	Phosphate uptake mg/100 g
T_1	4.0	5.607	0.487
T_2	4.6	6.127	0.507
T_3	5.3	6.540	0.515
T_4	5.0	6.747	0.513
T_5	7.0	6.537	0.547
T_6	7.3	6.790	0.547
T_7	8.6	6.310	0.553
T_8	10.3	6.807	0.567
T_9	9.6	6.887	0.540
T_{10}	12.0	7.943	0.530
T_{11}	12.3	7.547	0.513
T_{12}	13.3	7.617	0.553
T_{13}	13.6	7.950	0.553

T_{14}	15.0	7.840	0.523
T_{15}	14.3	8.103	0.637
T_{16}	16.0	9.523	0.637
T_{17}	14.0	8.697	0.577
CD at 5%	**1.953**	**1.116**	**N.S.**

The analysis of nodules produced on gram roots for their N and P contents are recorded in the table 14. The nitrogen content of root nodules of gram crop increased significantly in the main wheat crop with F.Y.M. The probable explanation for the increase of nitrogen in nodules may be due to more rhizobial and *Azotobacterin* in fixing the atmospheric and non symbiotic activity. Sufficient amount of nutrients required for the crop growth and nodule development may be available with the application of F.Y.M. plots receiving organic matter and phosphate have further increased the number of nodule formation as well as their nitrogen content.

The phosphate content in the root nodules was determined and recorded in table 14. It was noticed that P content was non-significant. The maximum P content in the root nodules was obtained in the plot receiveing *Azotobacterin* and *phosphobacterin* alongwith F.Y.M. and Sludge respectively. It appears from the data that the increase amount of phosphate availability may be due to organic matter and bacterial culture used in the main crop.

Table - 15

Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. Fertilizer on Gram Grain uptake of Crude Protein and Phosphate

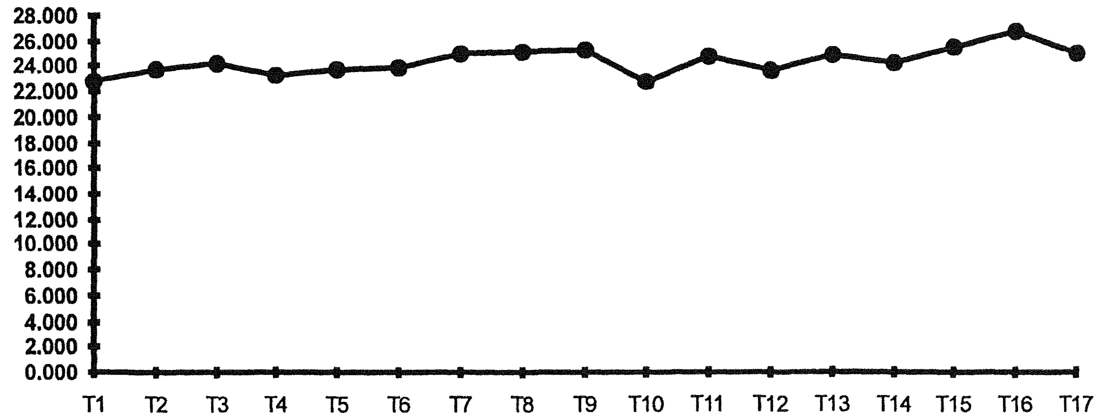
Treatment	Crude Protein g/100 g	Phosphate mg/100 g
T_1	22.88	416

T_2	23.68	431
T_3	24.18	435
T_4	23.21	455
T_5	23.76	448
T_6	23.98	437
T_7	25.00	441
T_8	25.16	442
T_9	25.37	452
T_{10}	22.88	450
T_{11}	24.84	459
T_{12}	23.75	453
T_{13}	25.00	469
T_{14}	24.32	448
T_{15}	25.63	463
T_{16}	26.84	483
T_{17}	25.17	459
CD Value at 5%	**1.09**	**28**

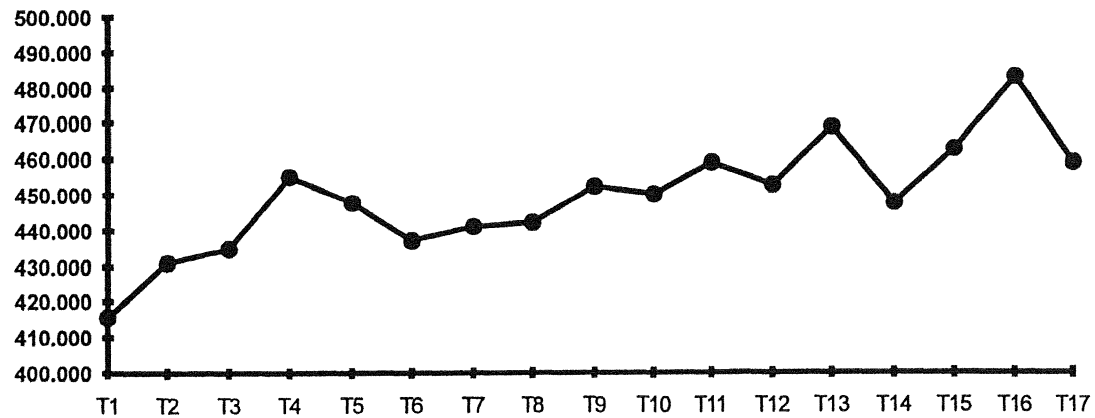
The increase of nitrogen and phosphate content in root nodules of the gram crop may influence better crop growth which may increase the productivity of the residual crop.

For evaluating the quality of gram crop the crude protein and phosphate contents were determined in grains as well as straw which are recroded in table 15. Crude protein content was found out from its nitrogen content and then multiplied with a factor 6.25 for giving its approximate value. The N/P ratio was also worked out which emphasizes the quality of the crop. The crude protein content of the gram grain was found to have 22.88 percent in

Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Gram Grain uptake of Crude Portein (g/100g) (Table - 15)



Residual Effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. fertilizers on Gram Grain uptake of Phosphate (mg/100g) (Table - 15)



the control plant and plot containing F.Y.M. 23.6 percent i.e. an increase of 0.8 percent was estimated due to F.Y.M. application.

The maximum crude protein in the grain was obtained to the extent of 26.17 percent in F.Y.M. + Sludge + *Azotobacterin* and *Phosphobacterin* treated plots in the main wheat crop. The result of the nutrient content was found to be significant in the residual crop also.

The residual effect of F.Y.M. and sludge on crude protein content in the gram grains was found to increase by 2.52 and 1.21 percent respectively. The cumulative effect of organic matter and sludge with *Azotobacterin* and *Phosphobacterin* inoculated plots furni shed an increased amount of available nutrient viz. nitrogen fixed through legumes and organic matter application alongwith *Azotobacterin.* Moreover *phosphobacterin* inoculation may release other macro and micro nutrients which was made available from F.Y.M. decomposition.

The phosphate content of the gram grain was also found to have 0.41 percent in the control plot and when F.Y.M. was applied the P content got increased by 15 mg/100g. The maximum P content was obtained in grains where F.Y.M. and sludge alongwith *Azotobacterin* and *Phosphobacterin* were incorporated in the main wheat crop.

Table - 16

Residual effect of Azotobacterin and Phosphobacterin with F.Y.M. + Sludge alongwith N.P.K. Fertilizer on Gram Straw uptake of Nitrogen and Phosphate

Treatment	Nitrogen % uptake	Phosphate % uptake	Ratio N/P
T_1	4.92	0.42	11.71
T_2	5.93	0.44	13.74

T_3	5.33	0.47	11.34
T_4	5.17	0.45	11.48
T_5	5.88	0.46	12.78
T_6	5.53	0.45	12.28
T_7	6.25	0.46	13.58
T_8	5.57	0.42	13.26
T_9	6.42	0.45	14.26
T_{10}	5.78	0.49	11.79
T_{11}	5.67	0.45	12.6
T_{12}	6.33	0.47	13.46
T_{13}	6.00	0.47	12.76
T_{14}	6.00	0.47	12.76
T_{15}	5.92	0.46	12.86
T_{16}	6.52	0.49	13.30
T_{17}	6.42	0.47	13.65
CD Value at 5%	**N.S.**	**N.S.**	

The composition of the gram straw particularly their N and P content and the N/P ratio have been recorded in table 16.

The N and P contents estimated in the straw of the gram crop was found to have 4.92 percent N and 0.42 percent P in the control set while F.Y.M. application has increased their N and P contents to the extent of 5.93% and 0.44% respectively in the residual crop. The maximum N content was reported in plots containing F.Y.M. + Sludge + *Azotobacterin* + *Phosphobacterin* to the extent of 6.5 percent and P content in the gram straw.

was found 0.49 percent. Gram straw is mostly used for cattle feeding and the quality of straw thus got improved by increasing their N and P contents. The higher yield as well as improved quality of straw as fodder can bring this type of integrated management of the gram crop which gave higher grain yield of better quality and may be used as pulse in our diets having increased amount of protein.

Table - 17

Physico-chemical Properties of Soil used under Field Experiment after Harvesting Gram Crop, 1999

Treatment	O C (%)	Total (%)	Available N kg/ha	Available P_2O_5 kg/ha	Available K_2O kg/ha
T_1	0.52	0.040	108.2	20.0	180.0
T_2	0.58	0.049	120.0	24.0	190.0
T_3	0.58	0.047	117.0	26.0	191.0
T_4	0.56	0.046	112.0	25.0	188.0
T_5	0.58	0.045	118.0	26.0	190.0
T_6	0.57	0.048	119.0	25.0	189.0
T_7	0.56	0.048	118.0	22.0	186.0
T_8	0.60	0.052	122.0	26.0	190.0
T_9	0.54	0.051	124.0	25.0	185.0
T_{10}	0.53	0.048	121.0	26.0	192.0
T_{11}	0.59	0.048	119.0	28.0	195.0
T_{12}	0.60	0.050	129.0	30.0	198.0
T_{13}	0.56	0.045	108.0	32.0	200.2

T_{14}	0.59	0.049	122.0	32.0	200.3
T_{15}	0.58	0.048	121.0	30.0	199.2
T_{16}	0.64	0.056	13.0	34.0	205.0
T_{17}	0.60	0.050	120.0	32.0	200.1

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The agriculture production has increased due to high yielding varieties and enhanced consumption of chemical fertilizers and water in India. Due to high cost of energy utilised in fertilizer industry resulting in increased price rise which may be a limiting factor for increasing agricultural production in future. It is, therefore, essential for us to evolve and adopt a strategy for nutrient supply by using a judicious combination of chemical fertilizer, organic manures and biofertilizers.

Biofertilizers are cultures of microbes which benefit the crop by providing nitrogen or phosphorus by rapid mineralization of organic materials. They may be classified as nitrogenous, phosphatic or cellulolytic depending on their physiological activities.

The most widely used biofertilizer, Rhizobium in association with legume can fix more than 100 kg N/ha in one season and in certain situation leave substantial quantity of nitrogen for the following crop. The use of blue green algae as a biofertilizer for rice has promising potential azolla in association with blue green algae fixes 100-150 kg N/ha annually from about 40-60 tons of bio mass. Natrajan et al, (1989)

The present investigation entitled 'Biofertilizer studies in soil and plant relationship' was conducted during 1996 - 1999 at the experimental research form of Sheila Dhar Institute of Soil Science, University of Allahabad.

Experiment -1 was laid out with lentil (*Lens esculenta*) variety Type-8 during Rabi season 1996-97. F.Y.M. and sludge were applied in soil at the rate of 12.5 t/ha and phosphate was applied as M.R.P. at the rate of 50 kg P_2O_5 as basal application. *R. leguminosarum* was inoculated in the lentil

seeds according to the requirement of the treatments as mentioned in the experimental layout. A set of experiment was laid out to incorporate half of the dose of F.Y.M. sludge and M.R.P. with or without Rhizobia inoculation.

The maximum crop height after 30, 60 and 90 days was noticed in Table-1 with selected treatments containing sludge, F.Y.M. alongwith M.R.P. having *Rhizobia* inoculation.

Table - 1 : Crop Height in cms after 30 Days Intervals

Treatment	30 DAS height in cms	60 DAS height in cms	90 DAS height in cms
T_1	10.2	20.4	35.8
T_{10}	12.0	26.33	43.80
T_{11}	12.4	26.33	43.50
T_{12}	12.8	26.33	44.13
T_{16}	15.7	30.00	47.36

The size and number of nodules in roots of the lentil crop was also observed. The application of F.Y.M. when applied alone gave a significant increase over the control whereas the Rhizobia inoculation has increased nodule numbers to more than the double. It was noticed that the nodules number got further increased in F.Y.M. and Rhizobia inoculated plots when supplemented with M.R.P. (Table-2).

Table - 2 : Number of nodules in different selected treatments

Treatment	Number of Nodules (average)
T_1	3.0
T_2	7.0
T_{13}	13.3
T_{14}	14.3
T_{16}	15.0

The nitrogen content of root nodules of lentil crop also increased significantly when F.Y.M. was applied in soil. (Table-3)

Table - 3 : Selected treatmentwise N uptake by root nodules

Treatment	N Uptake by Nodules (g/100g)
T_2	5.197
T_{14}	7.130
T_{16}	7.383

The phosphate content in the root nodules was found to increase significantly with the application of F.Y.M. also with the combination of M.R.P. when inoculated with *R. leguminosarum*.

The maximum P content in the root nodules was obtained in plots receiving F.Y.M. sludge, and M.R.P. alongwith *Rhizobium* (Table-4)

Table - 4 : Selected treatmentwise P Uptake by Root Nodules

Treatment	P uptake by Nodules (mg/100g)
T_1	0.39
T_2	0.480
T_4	0.407
T_{16}	0.590
T_{17}	0.587

The F.Y.M., M.R.P. and sludge application alongwith rhizobial inoculation gave the maximum grain and straw yield of about 20.0 q/ha that is double of the grain yield obtained in control plots. (Table - 5). It may be due to increased nutrient uptake by the crop.

Table - 5 : Selected treatmentwise Grain & Straw Yield

Treatment	Yield q/ha		Straw/Grain
	Grain	Straw	Ratio
T_1	9.6	19.5	2.0
T_{16}	20.0	29.1	1.4
T_{17}	19.2	28.5	1.4

The crude protein and phosphate content of the lentil grain was found to increase in the plots containing F.Y.M. with R. inoculation alongwith M.R.P. and sludge application. (Table - 6)

Table - 6 : Crude Protein and P. Content of the Lentil Grain

Treatment	Crude Protein g/100 g	Phosphate mg/100 g
T_{13}	25.400	429.000
T_{14}	25.300	423.333
T_{15}	24.800	430.667
T_{16}	25.133	441.667

Experiment - 2 was conducted to find out the response to *Azotobacterin* and *Phosphobacterin* inoculation on wheat (*Triticum aestivum*) at SDI experiment farm during 1997-98 with F.Y.M. sludge and N.P.K. combination.

The maximum crop height (Table-7) 30, 60 and 90 DAS was observed in treatments containing 1/2 N.P.K. dose i.e. 60 : 30 : 30 with *Azotobacterin* as well as *phosphobacterin.*

Table - 7 : Selected treatments, Crop Growth at 30 Days Intervals

Treatment	30 DAS height in cms	60 DAS height in cms	90 DAS height in cms
T_{1}	12.2	32.8	75.0
T_{14}	15.0	46.0	82.2
T_{16}	18.0	45.0	87.2
T_{17}	20.0	50.0	90.5

The inoculating *phosphobacterin* in F.Y.M. treated plot, the grain yield was recorded 28.5 q/ha i.e. increase of about 23 percent. (Table-8)

Table - 8 : Response of Phosphobacterin on Wheat

Treatment	Grain in q/ha	Straw in q/ha
T_1	20.0	38.0
T_2	25.2	43.5
T_{10}	28.5	50.0
T_{13}	30.0	52.5
T_{17}	30.0	52.3

Wheat grains were analysed for their N contents and found that 1.75 percent N in the control set. Inoculation of *Azotobacterin* as well as *phosphobacterin* had affected the N uptake separately as well as in their combinations. The maximum N uptake was found in treatment containing half of the N.P.K. dose where inoculation of *phosphobacterin* and *Azotobacterin* was conducted. (Table - 9)

Table - 9 : Selected treatmentwise N uptake by Wheat Crop

Treatment	N uptake in ppm
T_1	1.75
T_9	2.10
T_{13}	2.01
T_{17}	2.43

The wheat grains were analysed for their P uptake and was estimated 0.035% in the control set and with the F.Y.M. application the P content got increased to 0.044%. The maximum P-uptake was recorded in two sets of the

treatments that is one with half of the dose of N.P.K. (60 : 30 :30) inoculated with *Phosphobacterin* and the other in similar treatment where addition of *Azotobacterin* inoculation was carried out (Table - 10).

Table - 10 : P-uptake by Wheat as affected by Selected Treatments

Treatment	P uptake in ppm
T_1	0.035
T_2	0.044
T_{13}	0.049
T_{17}	0.049

The N and P contents in wheat straw were estimated 0.30% and 0.052% respectively in control set. The N uptake by straw got increased to 0.32%. A similar trend in the increase of N and P contents by wheat straw was obtained as influenced by other treatments as was observed in case of wheat grain. (Table - 11)

Table -11 : N & P Uptake by Wheat Straw

Treatment	N uptake in ppm	P uptake in ppm
T_1	0.300	0.052
T_2	0.320	0.053
T_{13}	0.440	0.065
T_{17}	0.480	0.069

Experiment - 3 A residual crop Gram *(Cicer arietinum)* variety Type-1 was grown in plot, where wheat was harvested after keeping fallow in the Kharif Season. The increased growth was

found due to the presence of sufficient nutrients after the harvest.

Where N.P.K. was applied in the first crop a significanct increase in the crop growth at two different stages reveals optimum nutrient present in the soil. Inoculation of *Azotobacterin* as well as *Phosphobacterin* in the main crop might have grown to a large bacterial population and their influence on mineralization processes have caused increase in the nutrient availability.

The maximum yield of grains and straw was obtained in plots F.Y.M. and sludge having *Azotobacterin* and *Phosphobacterin* inoculation in the main wheat crop to the extent of 15 q/ha over to control which yielded 10 q/ha. It shows 50 percent increase in the gram grain yield over the control. (Table - 12)

Table - 12 : Grain and Straw Yield of Gram in q/ha

Treatment	Grain q/ha	Straw q/ha
T_1	10.0	19.0
T_2	15.0	24.5

The maximum N and P content in the root nodules was obtained in the plots receiving *Azotobacterin* and *Phosphobacterin* alongwith F.Y.M. and sludge..

Table -13 : N & P uptake by gram root nodules

Treatment	N uptake mg/100g	P uptake mg/100g
T_{16}	9.523	0.637
T_{17}	8.697	0.577

The maximum N and P content was obtained in grains where F.Y.M. and sludge alongwith Azotobacterin and Phosphobacterin were incorporated in the main wheat crop (Table - 14).

Table -14 : Crude protein & P uptake by gram grains

Treatment	Crude Protein g/100g	P uptake mg/100g
T_1	22.88	416
T_{15}	25.63	463
T_{16}	26.84	483

The N and P contents estimated in the straw of the gram crop was found to have 4.92% N and 0.42% P in the control set while F.Y.M. application has increased their N and P content to the extent of 5.93% and 0.44% respectively in the residual crop. The maximum N content was reported in plots containing F.Y.M. + sludge + *Azotobacterin* + *Phosphobacterin* to the extent of 6.52% and P content in the grain straw was found 0.49%.

On the basis of the field trial experiments conducted at the Sheila Dhar Inst. of Soil Science presented in the thesis, the farmers are advised to reduce NPK recommended dose of the crop to 50% ie half of the NPK dose and apply organic manure like F.Y.M./compost etc. alongwith biofertilizers for maintenance of soil fertility and sustainable agricultural production.

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